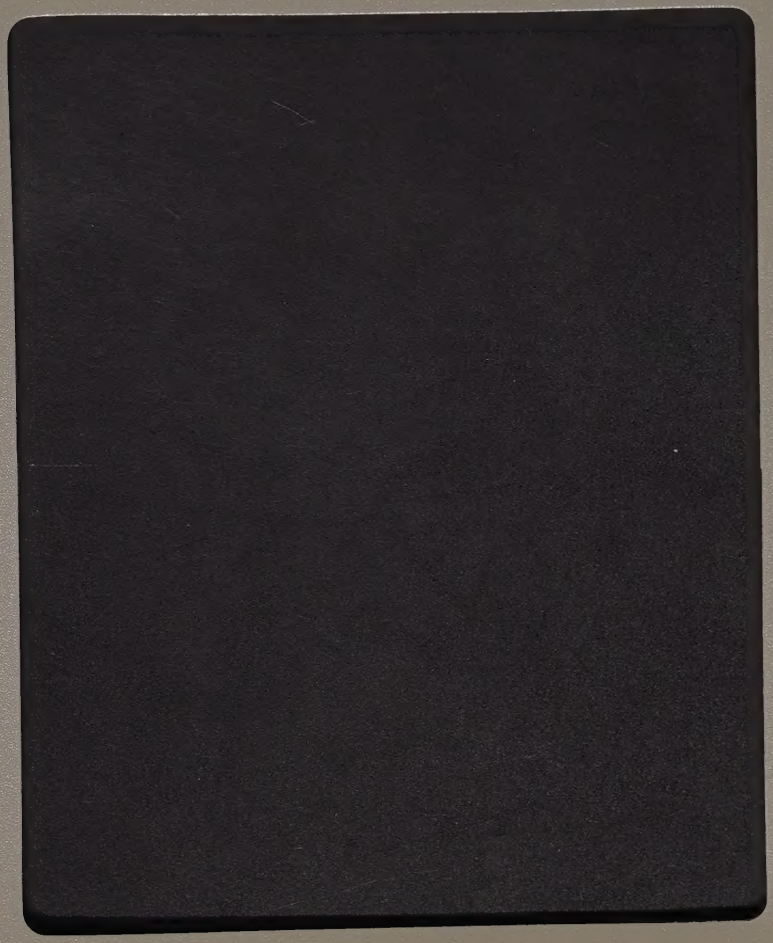
03M05C42

2160A
Digital Thermometer

Instruction Manual

FLUKE®



2160A
Digital Thermometer

Instruction Manual

P/N 445429
April 1976
Rev. 1 1/77

FLUKE®

©1981, John Fluke Mfg. Co., Inc., all rights reserved Litho in U.S.A.

WARRANTY

Notwithstanding any provision of any agreement the following warranty is exclusive:

The JOHN FLUKE MFG. CO., INC., warrants each instrument it manufactures to be free from defects in material and workmanship under normal use and service for the period of 1-year from date of purchase. This warranty extends only to the original purchaser. This warranty shall not apply to fuses, disposable batteries (rechargeable type batteries are warranted for 90-days), or any product or parts which have been subject to misuse, neglect, accident, or abnormal conditions of operations.

In the event of failure of a product covered by this warranty, John Fluke Mfg. Co., Inc., will repair and calibrate an instrument returned to an authorized Service Facility within 1 year of the original purchase; provided the warrantor's examination discloses to its satisfaction that the product was defective. The warrantor may, at its option, replace the product in lieu of repair. With regard to any instrument returned within 1 year of the original purchase, said repairs or replacement will be made without charge. If the failure has been caused by misuse, neglect, accident, or abnormal conditions of operations, repairs will be billed at a nominal cost. In such case, an estimate will be submitted before work is started, if requested.

THE FOREGOING WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS, OR ADEQUACY FOR ANY PARTICULAR PURPOSE OR USE. JOHN FLUKE MFG. CO., INC., SHALL NOT BE LIABLE FOR ANY SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER IN CONTRACT, TORT, OR OTHERWISE.

If any failure occurs, the following steps should be taken:

1. Notify the JOHN FLUKE MFG. CO., INC., or nearest Service facility, giving full details of the difficulty, and include the model number, type number, and serial number. On receipt of this information, service data, or shipping instructions will be forwarded to you.

2. On receipt of the shipping instructions, forward the instrument, transportation prepaid. Repairs will be made at the Service Facility and the instrument returned, transportation prepaid.

SHIPPING TO MANUFACTURER FOR REPAIR OR ADJUSTMENT

All shipments of JOHN FLUKE MFG. CO., INC., instruments should be made via United Parcel Service or "Best Way"* prepaid. The instrument should be shipped in the original packing carton; or if it is not available, use any suitable container that is rigid and of adequate size. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material.

CLAIM FOR DAMAGE IN SHIPMENT TO ORIGINAL PURCHASER

The instrument should be thoroughly inspected immediately upon original delivery to purchaser. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument is damaged in any way, a claim should be filed with the carrier immediately. (To obtain a quotation to repair shipment damage, contact the nearest Fluke Technical Center.) Final claim and negotiations with the carrier must be completed by the customer.

The JOHN FLUKE MFG. CO., INC, will be happy to answer all applications or use questions, which will enhance your use of this instrument. Please address your requests or correspondence to: JOHN FLUKE MFG. CO., INC., P.O. BOX C9090, EVERETT, WASHINGTON 98206, ATTN: Sales Dept. For European Customers: Fluke (Holland) B.V., P.O. Box 5053, 5004 EB, Tilburg, The Netherlands.

*For European customers, Air Freight prepaid.

John Fluke Mfg. Co., Inc., P.O. Box C9090, Everett, Washington 98206

Rev. 6/81

Table of Contents

SECTION	TITLE	PAGE
1	**INTRODUCTION AND SPECIFICATIONS**	**1-1**
	1-1. INTRODUCTION	1-1
	1-9. SPECIFICATIONS	1-2
2	**OPERATING INSTRUCTIONS**	**2-1**
	2-1. INTRODUCTION	2-1
	2-3. SHIPPING INFORMATION	2-1
	2-6. INPUT POWER	2-1
	2-9. PANEL INSTALLATION	2-1
	2-11. OPERATING FEATURES	2-2
	2-13. OPERATING NOTES	2-3
	2-15. Option Information	2-3
	2-17. Fuse Replacement	2-3
	2-19. Overload and Open Thermocouple Indication	2-3
	2-21. Temperature Scale, °C or °F	2-3
	2-23. Thermocouple Compatibility	2-4
	2-25. OPERATION	2-4
3	**THEORY OF OPERATION**	**3-1**
	3-1. INTRODUCTION	3-1
	3-3. OVERALL FUNCTIONAL DESCRIPTION	3-1
	3-7. CIRCUIT ANALYSIS	3-2
	3-9. Digital Section	3-2
	3-14. Analog Section	3-3

(continued on page ii)

TABLE OF CONTENTS, *continued*

SECTION	TITLE	PAGE
4	**MAINTENANCE**	**4-1**
	4-1. INTRODUCTION	4-1
	4-3. SERVICE INFORMATION	4-1
	4-6. GENERAL MAINTENANCE	4-1
	4-7. Access Information	4-1
	4-9. Cleaning	4-2
	4-11. Fuse Replacement	4-2
	4-13. Service Tools	4-2
	4-15. PERFORMANCE TEST	4-2
	4-17. Set Up Procedure	4-3
	4-19. Overload and Open Input	4-3
	4-21. Line Voltage Regulation	4-4
	4-23. Accuracy Test	4-4
	4-25. Internal Temperature Rise	4-4
	4-27. CALIBRATION	4-6
	4-34. Calibration Procedure	4-6
	4-42. CALIBRATION TECHNIQUES	4-8
	4-44. Thermocouple Accuracy Relating to the References Junction Calibration Technique	4-8
	4-47. Overall Accuracy	4-10
	4-49. TROUBLESHOOTING	4-10
5	**LIST OF REPLACEABLE PARTS**	**5-1**
	5-1. INTRODUCTION	5-1
	5-4. HOW TO OBTAIN PARTS	5-1
	5-7. USE CODE EFFECTIVITY LIST	5-1
6	**OPTION AND ACCESSORY INFORMATION**	**6-1**
	6-1. INTRODUCTION	6-1
	6-3. THERMOCOUPLE PROBES	6-1
	6-5. RACK MOUNTING PANELS	6-1
	6-7. TYPE SELECT PCB'S	6-2
	6-9. MODEL 2161A MULTIPOINT SELECTOR	6-2
	6-11. MODEL 2162A DIGITAL COMPARATOR	6-2
	6-13. DIGITAL OUTPUT UNIT, OPTION –02	6-2
	6-16. ANALOG OUTPUT UNIT, OPTION –04	6-2
7	**GENERAL INFORMATION**	**7-1**
8	**SCHEMATIC DIAGRAMS**	**8-1**

List of Illustrations

FIGURE	TITLE	PAGE
1-1.	2160A Outline Drawing	1-5
2-1.	2160A Controls, Indicators and Connectors	2-2
2-2.	Temperature Scale (°C/°F) Jumper Location	2-3
2-3.	Type Select PCB, Location and Installation Details	2-4
3-1.	2160A Simplified Block Diagram	3-1
3-2.	Measurement Cycle Waveforms	3-2
3-3.	Analog Section, Simplified Circuit Diagram	3-3
4-1.	Test Point and Adjustment Locations	4-3
4-2.	Voltage Divider-Calibrator Connection	4-4
4-3.	Room Temperature Lag Bath	4-5
4-4.	Reference Junction Compensation Circuitry	4-9
6-1.	P20 Series Thermocouple Probes	6-1
8-1.	A1A1 Thermometer PCB Assembly Component Location (2160A-1610)	8-2
8-2.	A1A1 Thermometer PCB Assembly Schematic (2160A-1010)	8-3
8-3.	A1A2 Display PCB Assembly Component Location (2160A-1621)	8-4
8-4.	A1A2 Display PCB Assembly Schematic (2160A-1021)	8-5
8-5.	A2 Type Select PCB Assembly Component Location (2160A-1612)	8-6
8-6.	A2 Type Select PCB Assembly Schematic (2160A-1012)	8-6

List of Tables

TABLE	TITLE	PAGE
1-1.	2160A Accessories	1-1
1-2.	2160A Options	1-2
1-3.	Specifications	1-2
2-1.	2160A Controls, Indicators and Connectors	2-3
4-1.	Test Equipment Requirements	4-2
4-2.	Performance Test Description	4-2
4-3.	Temperature Accuracy	4-5
4-4.	Reference-Junction Accuracy Limits	4-6
4-5.	Full Scale Calibration	4-6
4-6.	Bias Resistor Values	4-8
4-7.	Troubleshooting Guide	4-11
6-1.	2160A Options, Accessories and Documentation Sources	6-1

Section 1

Introduction & Specifications

1-1. INTRODUCTION

1-2. The Model 2160A Digital Thermometer is a panel-mounting, four-digit, thermocouple thermometer capable of resolving 1°C or 1°F over a temperature range of −200 to +2328°C or −328 to +3999°F. It features a four digit LED display, a reference-junction compensator (to eliminate the need for an ice bath reference junction), front-panel jumper selection of °C or °F, the choice of using any one of eight thermocouples types (J, K, E, T, R, S, B or C) as the input device, dual-slope measurement techniques and digital linearization of the thermocouple inputs. Several options and accessories are also available for use with the 2160A.

1-3. The front panel display consists of five, seven-segment, high-intensity LED's, and features leading-zero suppression. Four of the LED's are used to display numeric data, including a minus sign for negative temperature indications. The fifth LED displays the selected °C or °F scale character. An open-thermocouple detector causes the display to blink when an open circuit is sensed at the thermocouple input terminals.

1-4. Rear-panel, screw-type input connectors are provided for attaching the selected thermocouple. These terminals are an integral part of an isothermal block, and serve as the reference-junction for the reference-junction compensator. (The reference-junction compensator provides the physical and electrical equivalent of, and eliminates the need for, an ice bath reference junction at 0°C or 32°F.)

1-5. A jumper located behind the display lens can be positioned to select either the °C or °F temperature scale. The scale change can be made at any time and has no affect on calibration. The °C or °F LED displays the selected scale.

1-6. The actual measurement range of the 2160A is determined by the type of thermocouple being used as the input device. Any one of eight thermocouple types can be used; J, K, E, T, R, S, B or C. To ensure the proper linearization of the selected thermocouple input, a corresponding linearization program must be selected on the interior of the unit. Selection is accomplished by installing a type select pcb which corresponds to the input thermocouple. A single type select pcb is supplied with the unit to match the thermocouple type specified at the time of purchase. The remaining pcb's are individually available as accessories and are described in Table 1-1.

Table 1-1. 2160A ACCESSORIES

MODEL NO.	DESCRIPTION
P20J	J-Type Thermocouple Probe
P20K	K-Type Thermocouple Probe
P20T	T-Type Thermocouple Probe
M00-200-611	Rack Mounting Kit, Offset
M00-200-612	Rack Mounting Kit, Center
2160A-7031	Rack Mounting Panel, one unit
2160A-7032	Rack Mounting Panel, two units
2160A-7033	Rack Mounting Panel, three units
2160A-7016	J-Type Select PCB
2160A-7017	K-Type Select PCB
2160A-7019	E-Type Select PCB
2160A-7018	T-Type Select PCB
2160A-7012	R-Type Select PCB
2160A-7013	S-Type Select PCB
2160A-7014	B-Type Select PCB
2160A-7015	C-Type Select PCB
2160A-7022	Interface Cable
2161A	Multipoint Selector
2162A	Digital Comparator

1-7. Options available for use with the 2160A are listed and described in Table 1-2. Both options are field installable. Either one, but not both, of the options can be installed in a unit. Detailed information concerning each option is given in Section 6 of this manual, Option and Accessory Information.

Table 1-2. 2160A OPTIONS

OPTION NUMBER	DESCRIPTION
–02	Analog Output Unit
–04	Digital Output Unit

1-8. The 2160A is available in any one of three line power configurations: 100V ac, 50 to 440 Hz; 115V ac, 50 to 440 Hz; and 230V ac, 50 to 440 Hz. Specify the required configuration at the time of purchase.

1-9. SPECIFICATIONS

1-10. Specifications for the 2160A are given in Table 1-3.

Table 1-3. SPECIFICATIONS

ELECTRICAL

Compatible Thermocouple Types	Unit can be calibrated to operate with any one of the following thermocouple types: J, K, T, E, R, S, B or C
Measurement Method	Dual-slope integration over a 100 ms period
Zero Drift	None. Automatic zero correction
Reading Rate	2.5 readings per second
°C to °F Conversion	Jumper selectable
Input Characteristics	
Input Connections	Screw terminals on isothermal connector
Input Circuit	Two-wire, isolated
Input Impedance	$> 100\ M\Omega$
Input Current	< 500 pA
Source Impedance	$\leq 5k\Omega$. $5k\Omega$ causes $< 0.2°C$ (.36°F) error with k thermocouple
Overload	Display flashes when input voltage exceeds full-scale temperature range
Open Input	Display flashes to indicate open at input terminals
Maximum Input Voltage (without damage)	400V dc or ac peak continuously between inputs or between either input and ground
Maximum Common Mode Voltage (without damage)	400V dc or ac peak
Common Mode Rejection	≥ 120 dB @ 50, 60, 400 Hz $\pm 0.1\%$ with $1k\Omega$ source impedance unbalance
Normal Mode Rejection	≥ 60 dB @ 50, 60, 400 Hz $\pm 0.1\%$
Accuracy	See Table 1 for °C specifications and Table 2 for °F specifications
Response Time to Rated Accuracy	< 2.0 seconds
Linearization	Digital with eight selectable programs in LSI ROM
Linearization Programs	
J, K, T and E	32 straight line segments for positive inputs and 16 for negative inputs
R, S, B and C	48 straight line segments for positive inputs

Table 1-3. SPECIFICATIONS (Cont.)

Reference Junction Compensation

20 to 30°C (68 to 86°F)

J, K, T, E	0.025 degrees per degree
R, S	0.05 degrees per degree
C	0.02 degrees per degree

0 to 20°C, 30 to 50°C (32 to 68°F, 86 to 122°F)

J, K	0.032 degrees per degree
T, E	0.045 degrees per degree
R, S	0.07 degrees per degree
C	0.04 degrees per degree

Temperature Coefficient . . . . . 0.005% of reading per °C

Internal Temperature Rise . . . . . ≤5°C (9°F)

Table 1. ACCURACY SPECIFICATIONS °C

THERMOCOUPLE TYPE	TEMPERATURE RANGE °C	RESOLUTION AND REPEATABILITY (±C)	APPLICABLE TEMPERATURE RANGE °C	MAXIMUM ERROR INCLUDING NBS CONFORMITY (±°C)*				
				CALIBRATION ACCURACY	20 min. to 24 hrs. 23 to 27°C	90 Days 20 to 30°C	1 Year 15 to 35°C	NBS CONFORMITY (±°C)
J	−200 to 778	1	−200 to 0	1	1	1.5	1.5	.19
			0 to 778	1	1	1	1.5	.15
K	−200 to 1356	1	−200 to 0	1	1	1.5	2	.20
			0 to 1356	1	1	1.5	2	.18
T	−200 to 400	1	−200 to 0	1	1	1.5	2	.19
			0 to 400	1	1	1	1	.15
E	−200 to 1000	1	−200 to 0	1	1	1.5	2	.17
			0 to 1000	1	1	1	1.5	.18
R	0 to 1778	1	0 to 1778	1.5	1.5	2.5	3	.26
S	0 to 1778	1	0 to 1778	1.5	1.5	2	3	.22
B	533 to 1844	1	533 to 1844	1.5	1.5	2	2.5	.29
C	0 to 2328	1	0 to 2328	2	2	3	3	.36

* Includes reference junction and conformity errors. Excludes thermocouple errors.

Table 1-3. SPECIFICATIONS (Cont.)

Table 2 ACCURACY SPECIFICATIONS °F

THERMOCOUPLE TYPE	TEMPERATURE RANGE °F	RESOLUTION AND REPEATABILITY (±°F)	APPLICABLE TEMPERATURE RANGE °F	MAXIMUM ERROR INCLUDING NBS CONFORMITY (±°F)*				NBS CONFORMITY (±°F)
				CALIBRATION ACCURACY	20 min. to 24 hrs. 72 to 82°F	90 Days 68 to 86°F	1 Year 59 to 95°F	
J	–328 to 1432	1	–328 to 32 32 to 1432	1.5 1	1.5 1	2 1.5	2.5 2	0.27 0.2
K	–328 to 2472	1	–328 to 32 32 to 2472	2 1.5	2 1.5	2.5 2.5	3 3	0.28 0.26
T	–328 to 752	1	–328 to 32 32 to 752	1.5 1	1.5 1	2 1.5	3.5 2	0.3 0.2
E	–328 to 1832	1	–328 to 32 32 to 1832	1.5 1	1.5 1.5	2 2	3.5 2.5	0.25 0.25
R	32 to 3232	1	32 to 3232	2	2.5	4	5	0.4
S	32 to 3232	1	32 to 3232	2	2.5	3.5	4.5	0.33
B	992 to 3352	1	992 to 3352	2	2.5	3.5	4.5	0.45
C	32 to 3999	1	32 to 3999	3	3	5	5.5	.58

*Includes reference junction and conformity errors. Excludes thermocouple errors.

GENERAL

Type of Display . . . . . LED, 0.56 in high.

Power Requirements . . . . . 115V ac ± 10%, 50 to 440 Hz, 4W. 100V ac and 230V ac versions are also available.

Size . . . . . 1.88 in (H) x 3.78 in (W) x 8.05 in (D) (4.78 cm x 9.6 cm x 20.45 cm). Conforms to DIN standard. See Figure 1-1.

Weight . . . . . 1 lb. 10 oz. (0.737 kg)

ENVIRONMENTAL

Temperature

Operating . . . . . 0 to 50°C (32 to +122°F)

Storage . . . . . –40 to 75°C (–40 to 167°F)

Humidity

0 to 50°C (32 to 122°F) . . . . . 80% non-condensing

0 to 35°C (32 to 95°F) . . . . . 90% non-condensing

Shock and Vibration . . . . . Meets requirements of MIL Standard 810

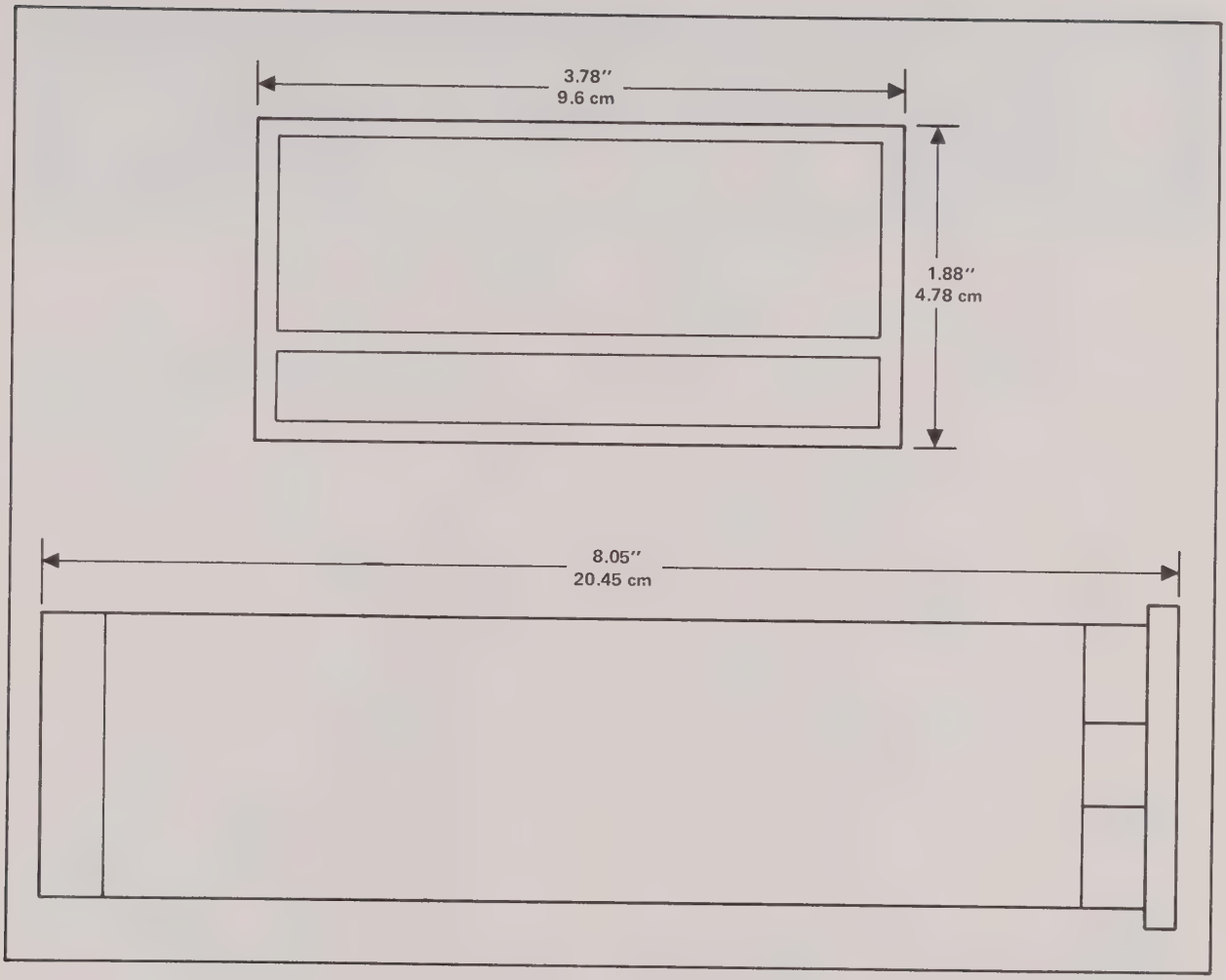
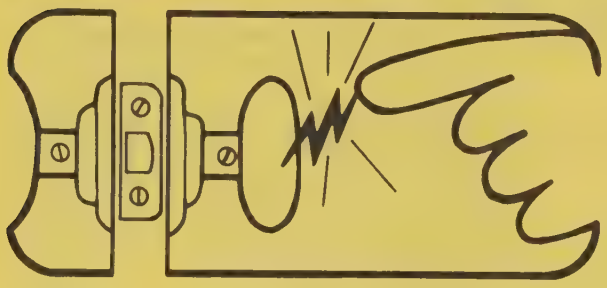


Figure 1-1. 2160A OUTLINE DRAWING

static awareness

A Message From

John Fluke Mfg. Co., Inc.

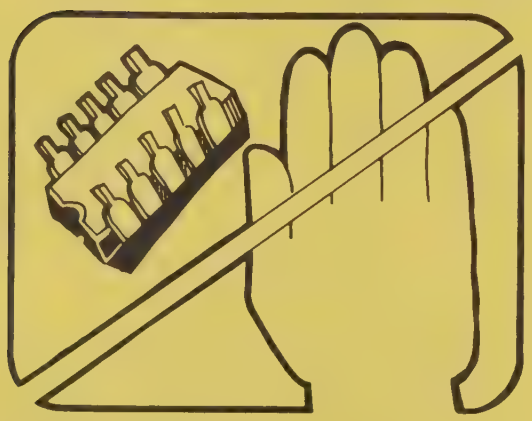


Some semiconductors and custom IC's can be damaged by electrostatic discharge during handling. This notice explains how you can minimize the chances of destroying such devices by:

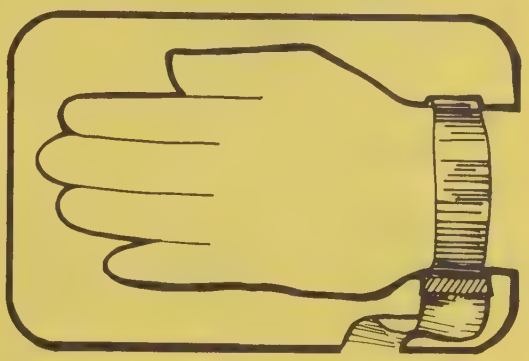
1. Knowing that there is a problem.
2. Learning the guidelines for handling them.
3. Using the procedures, and packaging and bench techniques that are recommended.

The Static Sensitive (S.S.) devices are identified in the Fluke technical manual parts list with the symbol "⊗"

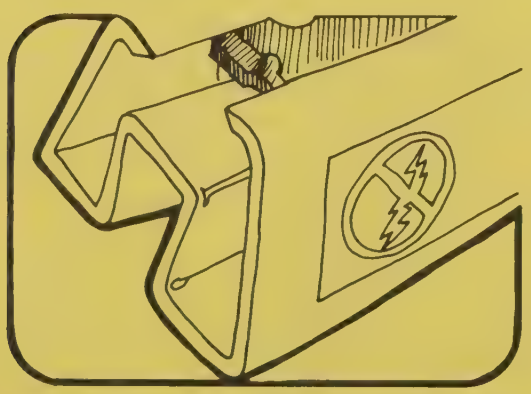
The following practices should be followed to minimize damage to S.S. devices.



1. MINIMIZE HANDLING

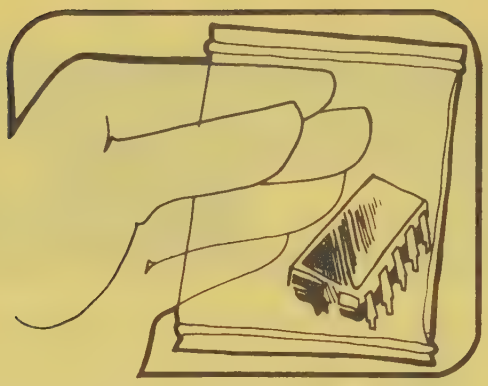


3. DISCHARGE PERSONAL STATIC BEFORE HANDLING DEVICES

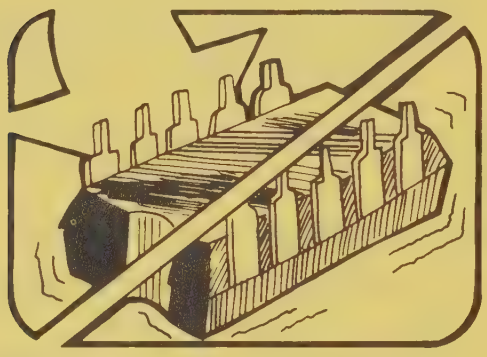


2. KEEP PARTS IN ORIGINAL CONTAINERS UNTIL READY FOR USE.

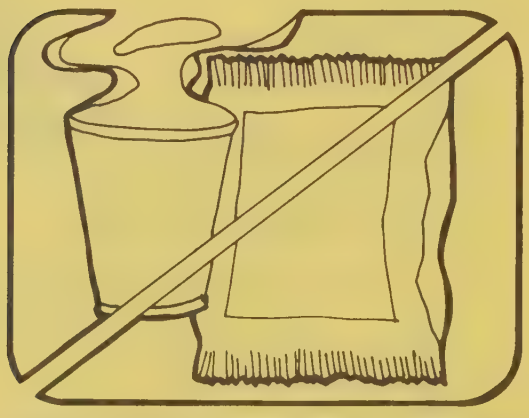
4. HANDLE S.S. DEVICES BY THE BODY



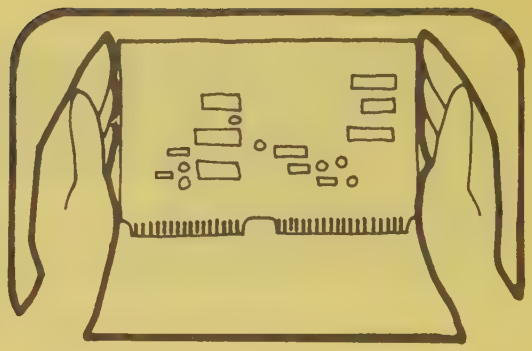
5. USE ANTI-STATIC CONTAINERS FOR HANDLING AND TRANSPORT



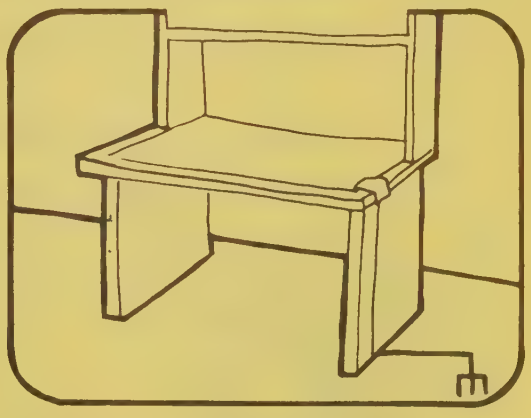
6. DO NOT SLIDE S.S. DEVICES OVER ANY SURFACE



7. AVOID PLASTIC, VINYL AND STYROFOAM® IN WORK AREA



8. WHEN REMOVING PLUG-IN ASSEMBLIES, HANDLE ONLY BY NON-CONDUCTIVE EDGES AND NEVER TOUCH OPEN EDGE CONNECTOR EXCEPT AT STATIC-FREE WORK STATION. PLACING SHORTING STRIPS ON EDGE CONNECTOR USUALLY PROVIDES COMPLETE PROTECTION TO INSTALLED SS DEVICES.



9. HANDLE S.S. DEVICES ONLY AT A STATIC-FREE WORK STATION
10. ONLY ANTI-STATIC TYPE SOLDER-SUCKERS SHOULD BE USED.
11. ONLY GROUNDED TIP SOLDERING IRONS SHOULD BE USED.

Anti-static bags, for storing S.S. devices or pcbs with these devices on them, can be ordered from the John Fluke Mfg. Co., Inc.. See section 5 in any Fluke technical manual for ordering instructions. Use the following part numbers when ordering these special bags.

John Fluke Part No.	Description
680892	5″ x 8″ Bag
680934	8″ x 10″ Bag
680942	8″ x 12″ Bag
680983	12″ x 16″ Bag
681023	18″ x 18″ Bag
Pink Poly Sheet 30″ x 60″ x 60 Mil P/N RC-AS-1200 $20.00	Wrist Strap P/N TL6-60 $7.00

PORTIONS REPRINTED
WITH PERMISSION FROM TEKTRONIX, INC.
AND GENERAL DYNAMICS, POMONA DIV.

® Dow Chemical

J0089C-07U8412/SE EN Litho in U.S.A.

Section 2

Operating Instructions

WARNING!

Due to the possible presence of lethal voltages, the procedures in paragraphs 2-17, 2-21 and 2-23 should be performed by qualified personnel only.

2-1. INTRODUCTION

2-2. This section of the manual contains information regarding installation and operation of the Model 2160A Digital Thermometer. It is recommended that the contents of this section be read and understood before any attempt is made to operate the instrument. Should any difficulties arise during operation, please contact your nearest Fluke Technical Service Center, or the John Fluke Mfg. Co., Inc. P.O. Box 43210, Mountlake Terrace, WA 98043, Tel (206) 774-2211. A list of Technical Service Centers is located in Section 7 of this manual.

2-3. SHIPPING INFORMATION

2-4. The 2160A is packaged and shipped in a foam-packed container. Upon receipt of the instrument, a thorough inspection should be made to reveal any possible shipping damage. Special instructions for inspection and claims are included in the shipping carton.

2-5. If reshipment of the instrument is necessary, the original container should be used. If the original container is not available, a new one can be obtained from the John Fluke Mfg. Co., Inc. Please reference the instrument model number when requesting a new shipping container.

2-6. INPUT POWER

2-7. The 2160A is factory wired to operate from one of three ac line voltages. These are: 100V ac, 50 to 440 Hz; 115V ac, 50 to 440 Hz; and 230V ac, 50 to 440 Hz. Before connecting the 2160A to the ac line, check to ensure that the instrument is wired to accommodate the local line voltage. A decal on the rear of the unit defines the particular line voltage required to operate the instrument.

2-8. The rear panel ac input connector is a three-prong, U-ground connector which permits the instrument to be connected, via the power cord, to the appropriate line voltage. The offset prong on this connector is connected to the 2160A power supply, and should be connected through the power cord to a high quality earth ground.

2-9. PANEL INSTALLATION

2-10. The 2160A is designed for installation in a console panel. The panel-mounting feature is an integral part of the instrument and does not require the use of a panel mounting kit. The unit conforms to DIN standards and will accommodate a panel thickness ranging from one-sixteenth of an inch to one-quarter of an inch. Use the following procedure to panel-mount the 2160A:

a. Locate the mounting position on the panel and cut a 1.772 inch-by-3.622 inch (4.5 cm x 9.2 cm) rectangular hole.

b. Remove the red, plastic display cover from the 2160A. Lift the cover at the bottom-center with a screw driver and continue to bow the cover until it pops out.

c. Locate the two screws on either side of the bezel and turn them ccw until their cam nuts are their rear-most position.

d. Slide the power cord and thermocouple (if attached) through the front-side of the prepared panel hole.

e. Slide the 2160A into the panel hole (back-side first) until its bezel is flush with the panel. Make sure the

cam nuts are inside their recesses during this procedure.

f. Hold the 2160A firmly against the panel, and turn both side panel screws cw until they are snug. Do not apply excessive pressure. If the procedure is executed properly, the cam nuts should be extended behind the panel and the instrument should be firmly held in place.

g. Place one side of the plastic display cover into position on the 2160A (frosted side out) and, bowing the cover away from the instrument, snap the other side into position.

2-11. OPERATING FEATURES

2-12. The location of all 2160A controls, indicators and connectors are shown in Figure 2-1, and described in Table 2-1.

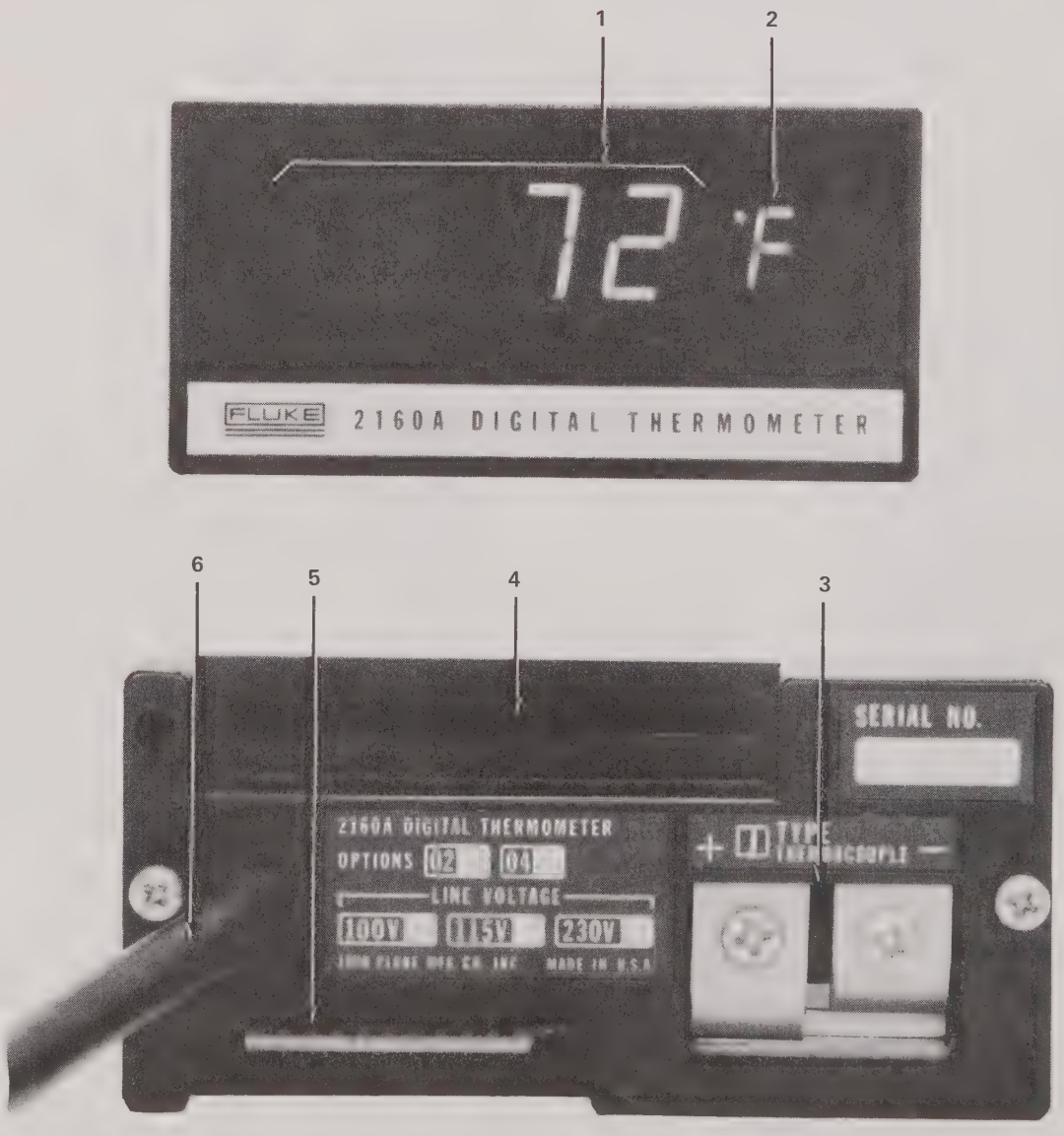


Figure 2-1. 2160A CONTROLS, INDICATORS AND CONNECTORS

Table 2-1. 2160A CONTROLS, INDICATORS AND CONNECTORS

REF. NO.	NAME	FUNCTION
1	Digital Display	Displays a four digit readout of the measured input temperature. Leading-zero suppression is also included. A minus sign is displayed for negative temperature measurements. The absence of a polarity sign indicates a positive temperature measurement.
2	Temperature Scale Indicator	Displays the temperature scale represented by the digital display data; °C or °F.
3	Thermocouple Input Connections	Provides screw-type terminals for connecting the thermocouple to the thermometer.
4	AOU/DOU I/O Port	Provides external access to the card-edge connector of the Digital Output Unit (Option –02) or the Analog Output Unit (Option –04), when installed.
5	Digital Comparator Connector	Provides the card-edge connections necessary to interface the 2160A with one or more 2162A Digital Comparators. See Section 6 of this manual for details concerning the 2162A.
6	Input Power Cable	Provides the means of connecting the instrument to ac line power.

2-13. OPERATING NOTES

2-14. The following paragraphs describe various conditions which should be considered before operating the 2160A.

2-15. Option Information

2-16. Supplementary operating instructions are necessary when operating a 2160A which is equipped with one of the available options. Detailed information regarding the operation of each available option is given in Section 6 of this manual, Option and Accessory Information.

2-17. Fuse Replacement

2-18. The ac line-input section of the 2160A power supply is fuse protected. The fuse is located on the interior of the unit near the power transformer. To access the fuse, disconnect the 2160A from line power, remove the rear-panel retaining screws located on both sides of the rear panel, and pull the pcb out the rear of the chassis. When replacement is necessary, use an MDL (Slo-blo) 1/16A fuse.

2-19. Overload and Open Thermocouple Indication

2-20. The front panel display, in addition to providing a measurement reading, is designed to serve as an overrange or open thermocouple indicator. When the measurement range of the input thermocouple is exceeded, or when the thermocouple inputs are open circuited, the display will blink. The blinking indication does not mean that the instrument is being exposed to a damaging input condition.

2-21. Temperature Scale, °C or °F

2-22. The 2160A temperature scale can be selected from the front panel for direct readings in °C or °F. The desired scale is selected by positioning a jumper located behind the red-plastic display cover. Use the following procedure to change temperature scales:

NOTE

When the 2160A is energized the selected temperature scale is displayed at the right of the readout.

a. Remove line power from the instrument.

b. Remove the red-plastic display cover from the 2160A. Lift the cover at the bottom center with a screw driver and continue to bow the cover until it pops out.

c. Locate the °C/°F jumper on the Display PCB as shown in Figure 2-2.

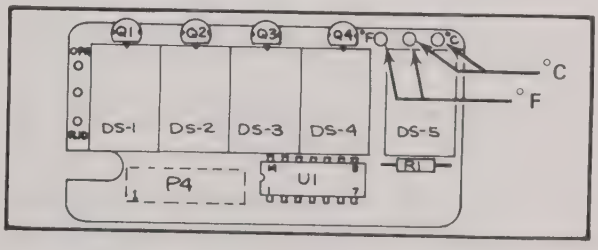


Figure 2-2. TEMP. SCALE (°C/°F) JUMPER LOCATION

d. Remove the jumper using a pair of long nose pliers, and install it in the desired °C or °F position.

e. Place one side of the plastic display cover into position on the 2160A (frosted side out) and, bowing the cover away from the instrument, snap the other side into position.

f. Energize the 2160A. The selected temperature scale should be displayed.

2-23. Thermocouple Compatibility

2-24. The 2160A is designed to operate in conjunction with a selected type of thermocouple probe. A decal on the rear of the unit identifies the compatible thermocouple type. When necessary, the 2160A can be modified in the field to accommodate any one of the following thermocouple types: J, K, E, T, R, S, B or C. Use the following procedure to change thermocouple type:

a. Refer to Table 1-1 in Section 1 of this manual and order the type select pcb which corresponds to the desired thermocouple type. These pcb's are low cost items and can be purchased from any of the John Fluke Technical Service Centers (See Section 7) or from the John Fluke Mfg. Co., Inc.

b. Disconnect the 2160A from line power.

c. Remove any ribbon-cable connectors that may be attached to the rear of the 2160A.

d. Remove the screws on both sides of the rear panel, and slide the panel away from the unit.

e. Grasp the thermocouple input connectors and carefully pull the pcb (s) out of the chassis.

f. Unplug and remove the currently installed type select pcb from the position shown in Figure 2-3, and install the new one in its place.

NOTE

The thermocouple type is etched on the type select pcb's. When properly installed the arrows on the pcb point toward the digital display.

g. Install the 2160A pcb in its chassis and secure the rear panel using the two side-center screws.

h. Connect the new type thermocouple to the thermocouple input terminals.

i. Place a piece of tape over the rear panel thermocouple type decal, and inscribe the new thermocouple type on it.

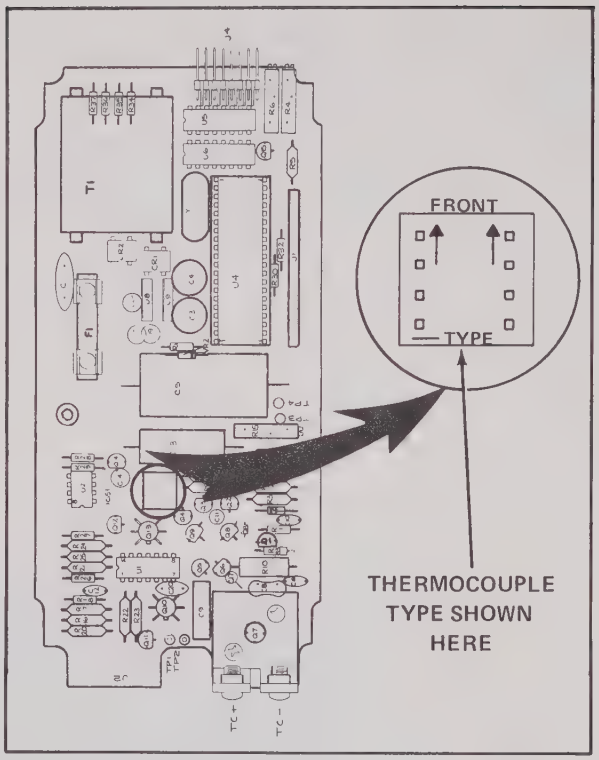


Figure 2-3. TYPE SELECT PCB, LOCATION AND INSTALLATION DETAILS

j. Connect the unit to line power, and complete the routine calibration procedure given in Section 4 (Maintenance) of this manual.

2-25. OPERATION

2-26. With reference to previous paragraphs in this section, operate the 2160A as follows:

a. Refer to the rear-panel decal and connect a compatible thermocouple probe to the thermocouple input terminals. Observe polarity shown on decal.

b. Select the desired temperature scale (°C or °F) using the procedure given earlier.

c. Energize the instrument by connecting the power cord to the appropriate ac line power as defined on the rear-panel decal.

d. Refer to Section 6 of this manual for instructions concerning the operation of the –02 and –04 options.

e. Expose the thermocouple probe to a temperature within its specified range (see Specifications in Section 1). The probe temperature will be displayed on the front panel.

Table 2-1. 2160A CONTROLS, INDICATORS AND CONNECTORS

REF. NO.	NAME	FUNCTION
1	Digital Display	Displays a four digit readout of the measured input temperature. Leading-zero suppression is also included. A minus sign is displayed for negative temperature measurements. The absence of a polarity sign indicates a positive temperature measurement.
2	Temperature Scale Indicator	Displays the temperature scale represented by the digital display data; °C or °F.
3	Thermocouple Input Connections	Provides screw-type terminals for connecting the thermocouple to the thermometer.
4	AOU/DOU I/O Port	Provides external access to the card-edge connector of the Digital Output Unit (Option –02) or the Analog Output Unit (Option –04), when installed.
5	Digital Comparator Connector	Provides the card-edge connections necessary to interface the 2160A with one or more 2162A Digital Comparators. See Section 6 of this manual for details concerning the 2162A.
6	Input Power Cable	Provides the means of connecting the instrument to ac line power.

2-13. OPERATING NOTES

2-14. The following paragraphs describe various conditions which should be considered before operating the 2160A.

2-15. Option Information

2-16. Supplementary operating instructions are necessary when operating a 2160A which is equipped with one of the available options. Detailed information regarding the operation of each available option is given in Section 6 of this manual, Option and Accessory Information.

2-17. Fuse Replacement

2-18. The ac line-input section of the 2160A power supply is fuse protected. The fuse is located on the interior of the unit near the power transformer. To access the fuse, disconnect the 2160A from line power, remove the rear-panel retaining screws located on both sides of the rear panel, and pull the pcb out the rear of the chassis. When replacement is necessary, use an MDL (Slo-blo) 1/16A fuse.

2-19. Overload and Open Thermocouple Indication

2-20. The front panel display, in addition to providing a measurement reading, is designed to serve as an overrange or open thermocouple indicator. When the measurement range of the input thermocouple is exceeded, or when the thermocouple inputs are open circuited, the display will blink. The blinking indication does not mean that the instrument is being exposed to a damaging input condition.

2-21. Temperature Scale, °C or °F

2-22. The 2160A temperature scale can be selected from the front panel for direct readings in °C or °F. The desired scale is selected by positioning a jumper located behind the red-plastic display cover. Use the following procedure to change temperature scales:

NOTE

When the 2160A is energized the selected temperature scale is displayed at the right of the readout.

a. Remove line power from the instrument.

b. Remove the red-plastic display cover from the 2160A. Lift the cover at the bottom center with a screw driver and continue to bow the cover until it pops out.

c. Locate the °C/°F jumper on the Display PCB as shown in Figure 2-2.

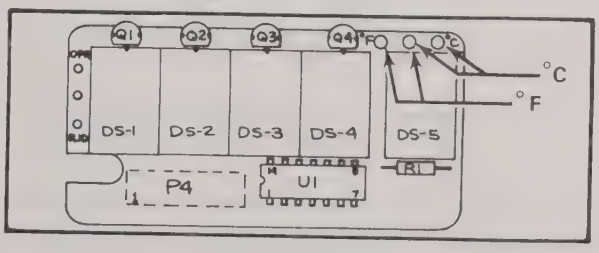


Figure 2-2. TEMP. SCALE (°C/°F) JUMPER LOCATION

d. Remove the jumper using a pair of long nose pliers, and install it in the desired °C or °F position.

e. Place one side of the plastic display cover into position on the 2160A (frosted side out) and, bowing the cover away from the instrument, snap the other side into position.

f. Energize the 2160A. The selected temperature scale should be displayed.

2-23. Thermocouple Compatibility

2-24. The 2160A is designed to operate in conjunction with a selected type of thermocouple probe. A decal on the rear of the unit identifies the compatible thermocouple type. When necessary, the 2160A can be modified in the field to accommodate any one of the following thermocouple types: J, K, E, T, R, S, B or C. Use the following procedure to change thermocouple type:

a. Refer to Table 1-1 in Section 1 of this manual and order the type select pcb which corresponds to the desired thermocouple type. These pcb's are low cost items and can be purchased from any of the John Fluke Technical Service Centers (See Section 7) or from the John Fluke Mfg. Co., Inc.

b. Disconnect the 2160A from line power.

c. Remove any ribbon-cable connectors that may be attached to the rear of the 2160A.

d. Remove the screws on both sides of the rear panel, and slide the panel away from the unit.

e. Grasp the thermocouple input connectors and carefully pull the pcb (s) out of the chassis.

f. Unplug and remove the currently installed type select pcb from the position shown in Figure 2-3, and install the new one in its place.

NOTE

The thermocouple type is etched on the type select pcb's. When properly installed the arrows on the pcb point toward the digital display.

g. Install the 2160A pcb in its chassis and secure the rear panel using the two side-center screws.

h. Connect the new type thermocouple to the thermocouple input terminals.

i. Place a piece of tape over the rear panel thermocouple type decal, and inscribe the new thermocouple type on it.

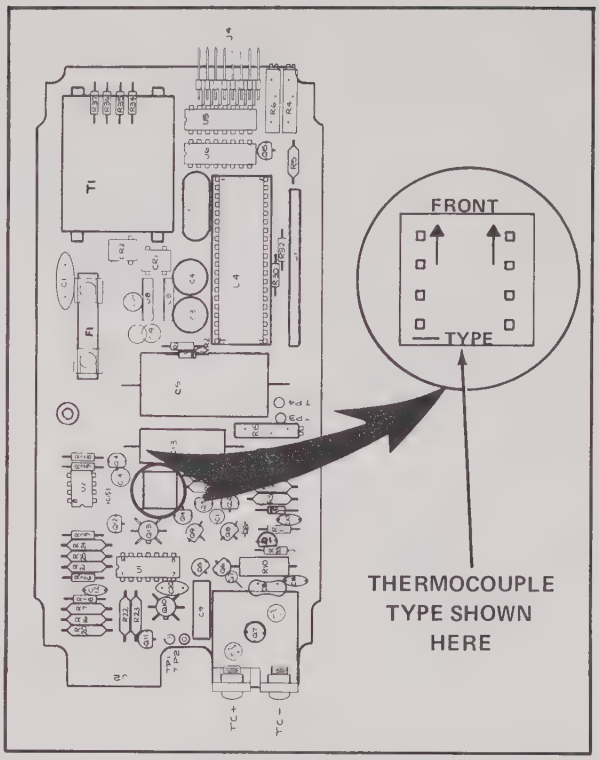


Figure 2-3. TYPE SELECT PCB, LOCATION AND INSTALLATION DETAILS

j. Connect the unit to line power, and complete the routine calibration procedure given in Section 4 (Maintenance) of this manual.

2-25. OPERATION

2-26. With reference to previous paragraphs in this section, operate the 2160A as follows:

a. Refer to the rear-panel decal and connect a compatible thermocouple probe to the thermocouple input terminals. Observe polarity shown on decal.

b. Select the desired temperature scale (°C or °F) using the procedure given earlier.

c. Energize the instrument by connecting the power cord to the appropriate ac line power as defined on the rear-panel decal.

d. Refer to Section 6 of this manual for instructions concerning the operation of the –02 and –04 options.

e. Expose the thermocouple probe to a temperature within its specified range (see Specifications in Section 1). The probe temperature will be displayed on the front panel.

Section 3
Theory of Operation

3-1. INTRODUCTION

3-2. This section of the manual contains an overall functional description followed by a circuit analysis of the 2160A. Simplified circuit diagrams and timing diagrams are included, as necessary, to supplement the text. Detailed schematics are given in Section 8 of this manual.

3-3. OVERALL FUNCTIONAL DESCRIPTION

3-4. The Model 2160A Digital Thermometer, as shown in Figure 3-1, is a four-digit, thermocouple thermometer capable of resolving 1°C or 1°F over a temperature range of −200 to +2328°C or −328 to +3999°F. It features a reference junction compensator (to eliminate the need for an ice-bath reference junction), dual-slope integration, LSI digital control logic (includes linearization programs for J, K, E, T, R, S, B and C type thermocouples), and a four-digit LED display.

3-5. In operation, the 2160A executes a continuous series of measurement cycles to update the temperature display. The measurement cycle is controlled entirely by an LSI digital IC, and includes three major subcycles; Auto-Zero period, Integrate period and Read period. Each subcycle controls the operation of the analog section of a dual-slope integrator which, in turn, generates a compare output to control the digital conversion performed by the LSI digital IC.

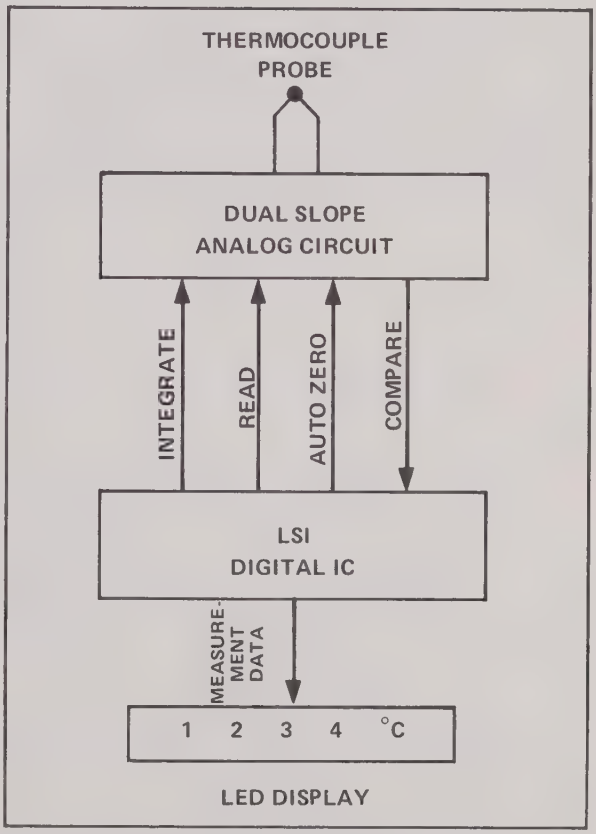


Figure 3-1. 2160A SIMPLIFIED BLOCK DIAGRAM

3-6. The configuration of the analog section of the 2160A, during each phase of the measurement cycle, is established by a combination of FET switches that are controlled by the LSI digital IC. The measurement cycle begins with the Auto-Zero period. During this period, the reference junction compensation voltage and the accumulated dc offset voltages present in the analog section are sampled and held by capacitors. These voltages are used later in the measurement cycle to cancel measurement errors introduced by offset voltages and reference junction voltage errors created at the input terminal connections. As a result, the final measurement is proportional to the thermocouple probe output voltage and does not include offset errors or reference junction voltage errors. During the Integrate period, the thermocouple input voltages (probe voltage and input terminal voltages) are applied to the integrator, and the algebraic sum of these voltages is integrated over a 100 ms period. At the end of this period, the thermocouple input voltages are removed from

the integrator and the Read period is started. A reference voltage is applied to the integrator during the Read period causing the integrator capacitor to be discharged at a linear rate. When the integrator output reaches zero, a compare signal is generated to end the Read period. The duration of the Read period is translated by the LSI digital IC to provide a digital indication proportional to the thermocouple probe temperature.

3-7. CIRCUIT ANALYSIS

3-8. Circuit analysis of the 2160A is discussed in two sections; digital and analog. The digital section is covered first, and particular attention is paid to the control it exercises on the analog section. The analysis of the analog section covers the analog measurement circuitry and the 2160A power supply.

3-9. Digital Section

3-10. The digital section of the 2160A consists of an LSI digital IC, a hex buffer, a seven-segment decoder/driver and an LED display. Its function is to convert the non-linear thermocouple probe voltage, as measured by the analog section, into a linear digital display. The display provides a direct reading of probe temperature in °C or °F.

3-11. The LSI digital IC contains all of the 2160A control logic and linearizing capability, and provides the hex buffer and seven-segment decoder with the data necessary to update the LED display. The linearization of the nonlinear input signal is accomplished by selecting one of eight programs which vary the rate at which the measurement counts are accumulated. The program is selected to match a particular thermocouple type. Program selection is accomplished by a series of plug-in type select pcb's which are available as accessories.

3-12. Measurement data is continuously strobed out of the LSI digital IC in bcd, character-serial format. At the end of each measurement cycle, an update flag is raised to signify that a new reading is available. When an overload occurs, the number of accumulated counts are stored and presented, along with a blanking pulse, as output data. The blanking pulse alternately turns the display on and off to indicate the presence of an overload.

3-13. The basic measurement cycle, as shown in Figure 3-2, comprises three subcycles; a 100 ms minimum Auto-Zero period, a 100 ms Integrate period, and a variable Read period. The auto-zero period is extended to 300 ms when an overload occurs. To accommodate settling times in the analog section, a 500 us hold signal is inserted at the beginning and at the end of the Integrate period.

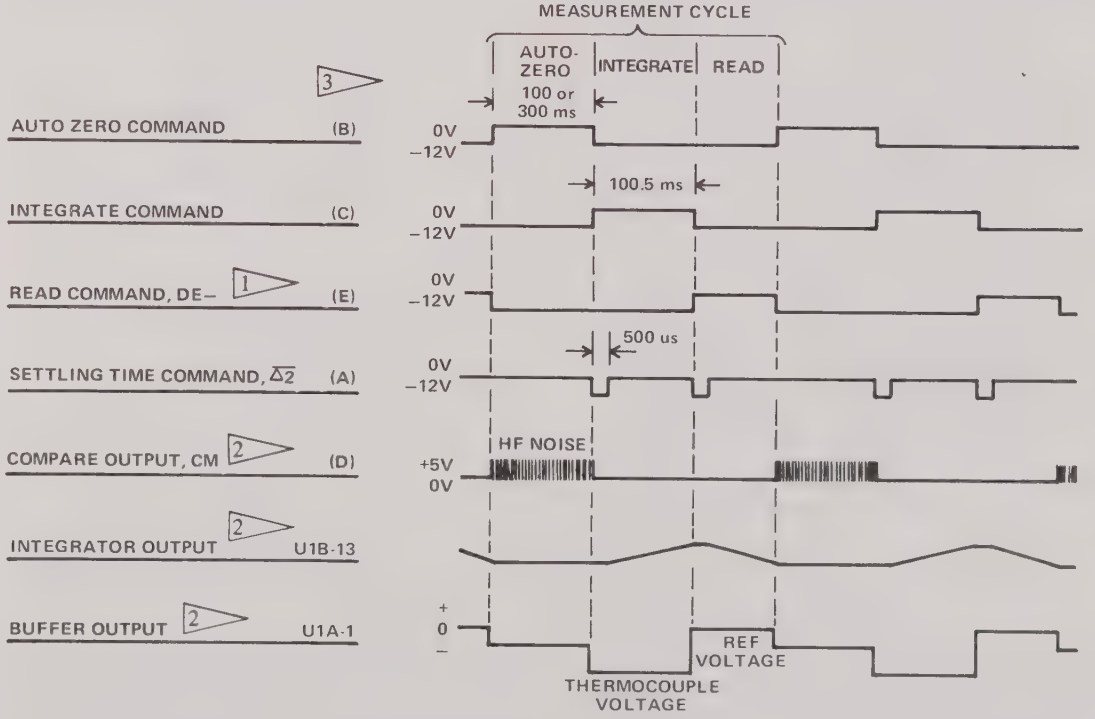


Figure 3-2. MEASUREMENT CYCLE WAVEFORMS

3-14. Analog Section

3-15. ANALOG MEASUREMENT CIRCUIT

3-16. The analog measurement circuit is shown in simplified form in Figure 3-3. It consists of a thermocouple input circuit, a reference-junction compensator, a voltage reference, a Buffer Amplifier, an Integrator, a Comparator, and a combination of FET switches. The switches are shown in their open state and are closed by the measurement cycle commands generated by the LSI digital IC. Each switch is assigned a letter designation which corresponds to a measurement cycle command shown in Figure 3-2.

3-17. The Thermocouple Input circuit consists of an R-C filter and a pair of voltage protection diodes. The difference between the thermocouple probe voltage and the input terminal voltage is passed through the filter and appears at the arm of switch C.

3-18. The Reference-Junction Compensator consists of an isothermal block, a pair of screw type input terminals, and a transistor temperature sensor. The isothermal block maintains a known temperature differential between the input terminals and the temperature sensing transistor. Thermocouple voltages introduced by the dissimilar metals at the input terminals vary as the isothermal block adjusts to ambient temperature. Temperature changes are sensed by the forward-biased transistor which produces a correction voltage equivalent to the thermocouple voltage created at the input terminals. Predictable characteristics of a forward-biased P-N junction allow the Reference-Junction Compensator to function over a wide temperature range. The correction voltage is matched to the thermocouple probe type by a selected Offset Resistor which is supplied on a plug-in type select pcb. The correction voltage appears at the arm of switch B1.

3-19. The voltage reference consists of a resistor divider which is supplied by an accurate 6.4V dc reference voltage. The divider is calibrated to match the thermocouple probe type by a selected resistor on the plug-in type select pcb. Two voltages are available at the divider outputs; 0.5 x V ref, and 1.5 x V ref. These voltages appear at the arms of switches B2 and E, respectively.

3-20. The Buffer, Integrator and Comparator amplifiers combine to perform the analog functions of the Integrate, Read and Auto-Zero periods. The Buffer is used to provide integrator inputs during all three periods. The Integrator integrates the Buffer output voltage during the Integrate and Read periods, and functions, in combination with the Comparator, as a closed-loop amplifier during the Auto-Zero period.

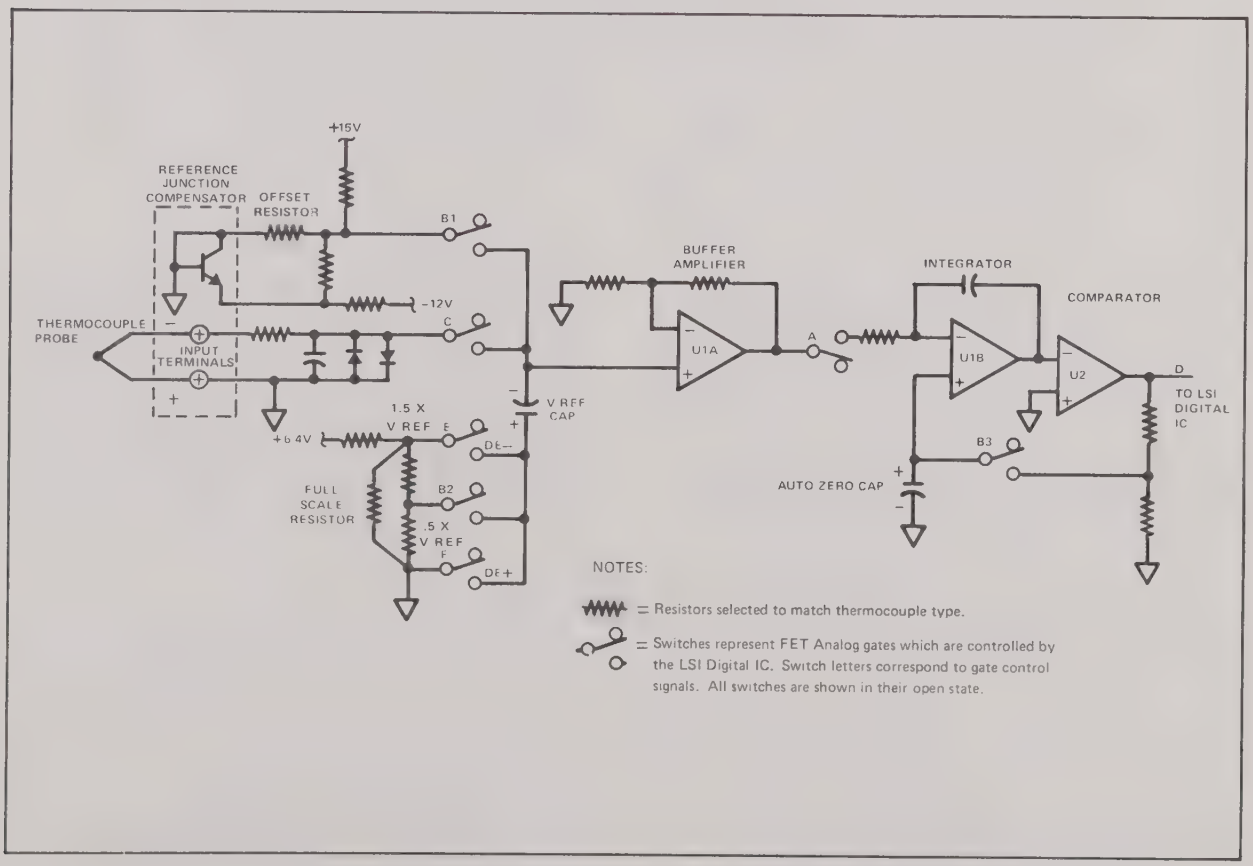


Figure 3-3. ANALOG SECTION, SIMPLIFIED CIRCUIT DIAGRAM

3-21. During the first phase of each measurement cycle, the analog section goes through an Auto-Zero period. During this time, three auto-zero switches (B1, B2 and B3) are closed by the Auto Zero command from the LSI digital IC. Two of the switches (B1 and B2) charge the V ref capacitor to a level equal to the algebraic sum of the 0.5 x V ref output, plus the correction voltage generated by the Reference-Junction Compensator. At the same time, the correction voltage is amplified by the Buffer Amplifier and presented through switch A to the Integrator input. The third switch (B3) connects the Integrator and Comparator in a closed loop configuration and allows the Auto-Zero capacitor to charge to a value which is proportional to the Reference-Junction-Compensator correction voltage plus the offset voltages present in the Buffer, Integrator and Comparator amplifiers. At the end of the measurement cycle switches B1, B2 and B3 are opened. The V ref capacitor and the Auto-Zero capacitor retain their charge for use later in the measurement cycle.

3-22. The Integrate period starts on the leading edge of the Integrate Command from the LSI digital IC; switch A is open and switch C is closed. The thermocouple input voltage is applied through switch C to the Buffer input. After a 500 us settling period, switch A closes and the Buffer output voltage is applied to the Integrator input for 100 ms. As the integrator capacitor charges, the Integrator drives the Comparator output to either 0 or +5V dc to indicate the polarity of the thermocouple input voltage, positive or negative, respectively. The comparator output is sent to the LSI digital IC for use during the Read period. At the end of the Integrate period, the integrator capacitor is charged to a level and polarity that is proportional to the thermocouple probe voltage and switch C returns to its open state.

3-23. The Read period starts at the end of the Integrate period and one of two Read Modes is enabled depending upon the input polarity sensed by the comparator during the Integrate period. If a positive input is sensed, a DE– Read Mode is enabled. Similarly a DE+ Read Mode is enabled when a negative input is sensed.

3-24. If the DE– Read Mode is commanded, switch A is opened and E is closed. Switch E applies a 1.5 x V ref input to the positive side of the V ref capacitor. This voltage is algebraically added to the voltage stored in the V ref capacitor during the previous Auto-Zero period (0.5 x V ref + Reference-Junction-Compensator voltage). As a result, the input to the Buffer Amplifier is a positive voltage equal to V ref plus the Reference Junction-Compensator voltage.

3-25. If the DE+ Read Mode is commanded, switch A is opened and F is closed. Switch F grounds the positive side of the V ref capacitor and causes the Buffer amplifier input to be driven to the voltage stored in the V ref capacitor during the previous Auto-Zero period (0.5 x V ref + Reference-Junction Compensator voltage). As a result, the input to the Buffer Amplifier is a negative voltage equal to 0.5 x V ref plus the Reference-Junction-Compensator voltage.

3-26. After a 500 us settling time, switch A closes and the Buffer output voltage is applied to the Integrator input. This causes the integrator capacitor to discharge at a linear rate determined by the reference voltage. The discharge continuses until the integrator output voltage reaches zero volts, the level existing prior to the integrate period. This level is sensed by the Comparator which signals the LSI digital IC to terminate the A/D conversion of measurement data.

3-27. Offset voltages present during the Integrate and Read periods are cancelled out by offset voltages that were sampled and held during the Auto-Zero period. However, the Reference-Junction-Compensator voltage (also sampled and held during Auto Zero) is added to the integrator voltage during the Integrate period. As a result, the displayed temperature is equal to the thermocouple probe temperature.

3-28. POWER SUPPLY

3-29. The 2160A power supply consists of a power transformer, fuse, power input cord, and regulating circuitry. The function of the power supply is to provide +5, +6.8, +15 and −12V dc operating voltages for the 2160A circuitry. In addition a +5V ac output is available for use by ground-isolated output options. The +6.8, +15 and −12V dc supplies are regulated, and the +5V dc supply is unregulated. All operating voltages are generated using conventional regulating and/or isolating techniques. Refer to the detailed schematic in Section 8 of this manual.

Section 4
Maintenance

WARNING!

THESE SERVICING INSTRUCTIONS ARE FOR USE BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING OTHER THAN THAT CONTAINED IN THE OPERATING INSTRUCTIONS UNLESS YOU ARE QUALIFIED TO DO SO.

4-1. INTRODUCTION

4-2. This section of the manual provides information about warranty, factory service, maintenance, performance testing, routine recalibration and recalibration after repair. The performance test is recommended when the instrument is received and later as a preventive maintenance tool or for testing after repair. The test verifies performance at several temperatures within the range of a given thermocouple type. Specifications are provided both for annual and for a more precise 90-day performance-testing cycle.

4-3. SERVICE INFORMATION

4-4. The instrument is warranted for a period of one year upon delivery to the original purchaser. The WARRANTY is located on the back of the title page located in the front of this manual.

4-5. Factory authorized calibration and service for each Fluke product is available at various world-wide locations. A complete list of these service centers is included in Section 7 of this manual. If requested, an estimate will be provided to the customer before any work is begun on instruments that are beyond the warranty period.

4-6. GENERAL MAINTENANCE

4-7. Access Information

4-8. Removal of the instrument from its case is necessary only for maintenance. Routine calibration can be done without such removal.

a. Calibration access can be obtained by removing the red-plastic display lens on the front panel. Lift the bottom-center of the lens with a small screw driver until the lens pops out of position. The lens is replaced by placing one side into position and then bowing the lens away from the front panel until the other side can be pushed into position. When the lens is released, it secures itself in position.

b. Maintenance access to the display and main pcb assemblies is achieved by removing the rear-panel retaining screws located on each side of the rear panel, and then pulling the main pcb assembly and mylar insulation sheet from the rear of the case. Line power should be disconnected from the thermometer when removing or installing pcb's.

4-9. Cleaning

4-10. Clean the instrument periodically to remove dust, grease and other contamination. Use the following procedure:

CAUTION!

Do not use aromatic hydrocarbons or chlorinated solvents for cleaning. They will react with plastic materials used in manufacture of the instrument.

a. Clean the front panel and case with a soft cloth dampened with a mild solution of detergent and water.

b. Clean the surface of the pcb using clean dry air at low pressure (≤20 psi). If grease is encountered, spray with Freon T. F. Degreaser or anhydrous alcohol and remove grime with clean dry air at low pressure.

4-11. Fuse Replacement

WARNING!

DISCONNECT THE UNIT FROM LINE POWER BEFORE ATTEMPTING FUSE REPLACEMENT.

4-12. The input power fuse is located on the interior of the unit near the power transformer. If replacement is necessary, use an MDL (Slo-blo) 1/16A fuse.

4-13. Service Tools

4-14. No special tools are required for maintenance or repair.

4-15. PERFORMANCE TEST

4-16. Table 4-1 lists the equipment required for performance testing and recalibration. If the recommended model of test equipment is not available, a substitute that meets the minimum use specifications may be used. Table 4-2 outlines the Performance Test. A Performance Checklist at the end of this section may be reproduced or removed to provide a written record of results. The Performance Test verifies instrument performance to specifications for initial acceptance or for maintenance. (Periodic recalibration requires the calibration procedure beginning in paragraph 4-27). If the thermometer fails to meet specifications, it requires recalibration or repair. Review Table 4-2, then continue.

NOTE

The Performance Test should be conducted at an ambient temperature of 25 ± 2° C (77 ± 3.6° F).

Table 4-1. TEST EQUIPMENT REQUIREMENTS

TEST EQUIPMENT	MINIMUM USE SPECIFICATIONS	RECOMMENDED MODEL
Thermocouple Probes	Type J,K,T,E,R,S,C ANSI C96.1 (Select type compatible with thermometer)	Omega TJ36 Series, Grounded Sheath
Mercury, thermometer (either °C or °F)	0.02°C Resolution 0.05°F Resolution	Princo Model ASTM-56C Princo Model ASTM-56F
Dewar Flask/Cap	1-pint capacity	Thermos
DC Voltage Calibrator	Output Voltage: 0 to 10V Accuracy: 0.002% Resolution: 10 mV	Fluke Model 343A
Voltage Divider 100:1 or Kelvin-Varley Divider (Shunt output with 1 uf capacitor)	Ratio: 0.005%	Fluke A21-5 or Fluke 720A or Fluke 750A
Variable Line-Voltage Transformer	100, 115, 230V ac, as required, ±10%	General Radio VARIAC W5HM
Decade Resistor	Accuracy: 1% Ranges: 1K, 10K and 100K	General Radio 1434

Table 4-2. PERFORMANCE TEST DESCRIPTION

TEST	PERFORMANCE SPECIFICATIONS	TEST METHOD	PARAGRAPH NO.
Setup	– – – –	– – – –	4-17
Overload and Open Input Test	The display flashes to indicate both over range input voltages and open input terminals.	An over range voltage is applied to the thermocouple input terminals, and the input terminals are open circuited.	4-19
Line Voltage Regulation	Satisfactory performance with any line voltage within ±10% of nominal; 100, 115 or 230V ac.	The display is monitored during the accuracy test as the line voltage is varied.	4-21
Accuracy Test	Temperature Accuracy as stated in Table 4-3	Known input voltages are substituted for the thermocouple inputs. Cardinal-point checks ensure accuracy over the entire temperature range.	4-23
Internal Temperature Rise	<5.0°C (9.0°F) above ambient	The thermocouple input terminals are shorted and the temperature of the reference junction is displayed.	4-25

4-17. Set-up Procedure

4-18. The following steps prepare for performance testing.

a. Remove the thermometer from its case.

b. Locate the RJD jumper on the display pcb (See Figure 4-1) and set it to the RJD position. (This defeats the reference-junction circuitry.)

c. Connect a voltage divider to a dc voltage calibrator as in Figure 4-2. (See Table 4-1 for specifications.)

d. Connect the voltage-divider output to the thermometer input terminals. Match polarity.

e. Connect a variable line-power transformer to line power and adjust the output to the nominal line voltage at which the thermometer is designed to operate; 100, 115, or 230V ac.

f. Connect a power cord between the transformer output and the thermometer ac line connector.

g. Set the TEMP-scale jumper to °F or °C. (See Figure 4-1.)

h. Set the calibrator to zero volts output, 10 volt range, and turn it on.

4-19. Overload and Open Input

4-20. The following procedure tests the thermometer overload and open-circuit detectors:

a. Set the calibrator output to 10V dc. The thermometer display should begin to flash. While the display is lit, it should read the high end of the temperature range assigned to the compatible thermocouple type:

J	=	1432° F	or	778° C
K	=	2472° F	or	1356° C
T	=	752° F	or	400° C
E	=	1832° F	or	1000° C
R	=	3232° F	or	1778° C
S	=	3232° F	or	1778° C
B	=	3352° F	or	1844° C
C	=	3999° F	or	2328° C

b. Set the calibrator output to OV dc.

c. Remove the input connections at the thermometer thermocouple input terminals. The display should begin to flash and read the low end of the temperature range except B which will display 32° F or

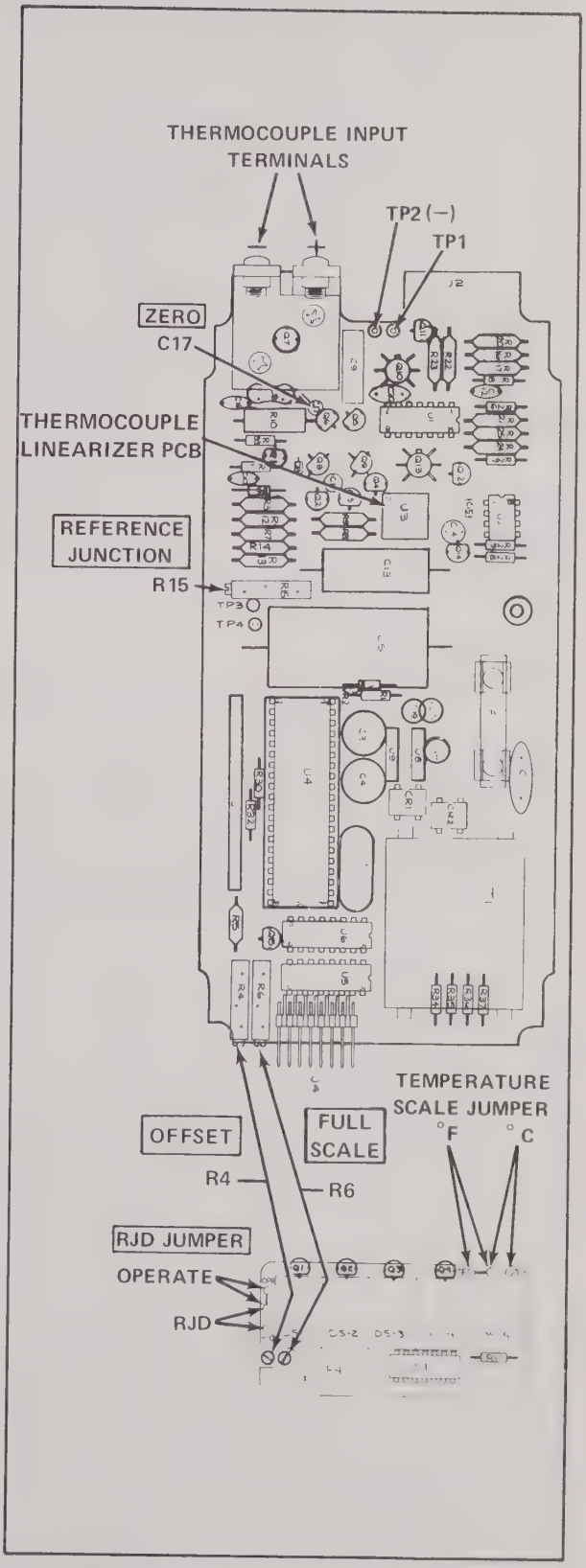


Figure 4-1. TEST POINT AND ADJUSTMENT LOCATIONS

0°C. (Note: The low end of the B range is +533°C or +992°F.)

J	=	-328° F	or	-200° C
K	=	-328° F	or	-200° C
T	=	-328° F	or	-200° C
E	=	-328° F	or	-200° C
R	=	32° F	or	0° C
S	=	32° F	or	0° C
B	=	32° F	or	0° C
C	=	32° F	or	0° C

d. This completes the Overload and Open-Input test.

4-21. Line Voltage Regulation

4-22. Line voltage regulation is tested in conjunction with the accuracy test given in the following paragraphs. As the accuracy test is executed, vary the line voltage ± 10% with the variable line-power transformer to ensure the proper operation within the line-voltage limits.

4-23. Accuracy Test

4-24. The following procedure tests the accuracy of the thermometer.

a. Connect the voltage-divider leads to the thermocouple input terminals. Match polarity.

b. Refer to Table 4-3 and select the group of values that correspond to the thermocouple type used with the thermometer.

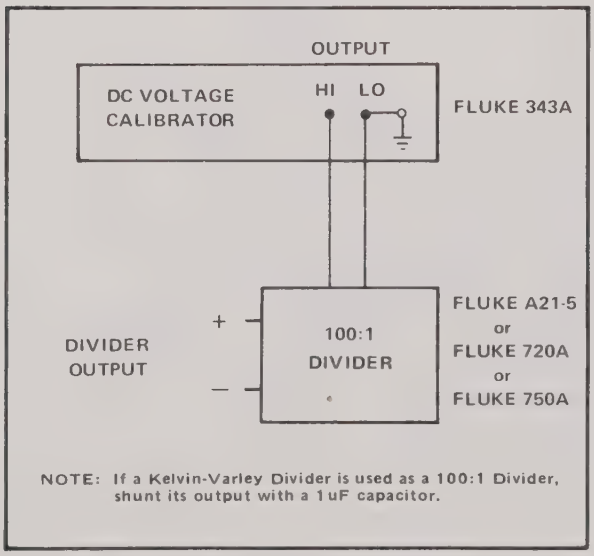


Figure 4-2. VOLTAGE DIVIDER–CALIBRATOR CONNECTION

c. Sequentially, set the calibrator to obtain each of the divider output voltages listed within the selected group, and check the thermometer display against the appropriate display limits; 90-day or 1-year. Vary the ac voltage over the specified ± 10% operating range. Check to see that the thermometer is still reading within accuracy specifications.

d. Remove the voltage divider from the thermometer input.

e. Set the RJD jumper to the operate position.

f. Install the thermometer, with mylar insulation sheet underneath, in its case.

g. Connect a thermocouple of the appropriate type to the thermocouple input terminals. Match polarity. J, K, T and E thermocouples have a red wire for the negative lead. Refer to the manufacturer for R, S, and C color coding.

h. Place the thermocouple in a room-temperature lag bath. (See Figure 4-3 for an illustration of lag-bath construction. Two holes should be drilled in the thermos lid to provide a snug fit for the mercury thermometer and thermocouple probe.)

i. Refer to Table 4-4. Determine if the thermometer display is within the specified range of the lag-bath temperature reading.

NOTE

Allow sufficient time for the mercury thermometer to come to a stable lag-bath temperature reading.

j. This completes the accuracy test portion of the Performance Test.

4-25. Internal Temperature Rise

4-26. The following procedure measures the thermometer's internal temperature as sensed by the reference junction:

a. Connect a copper wire between the thermocouple input terminals (in place of the thermocouple leads used in the preceding test).

NOTE

This procedure assumes that the thermometer has been energized for at least 30 minutes.

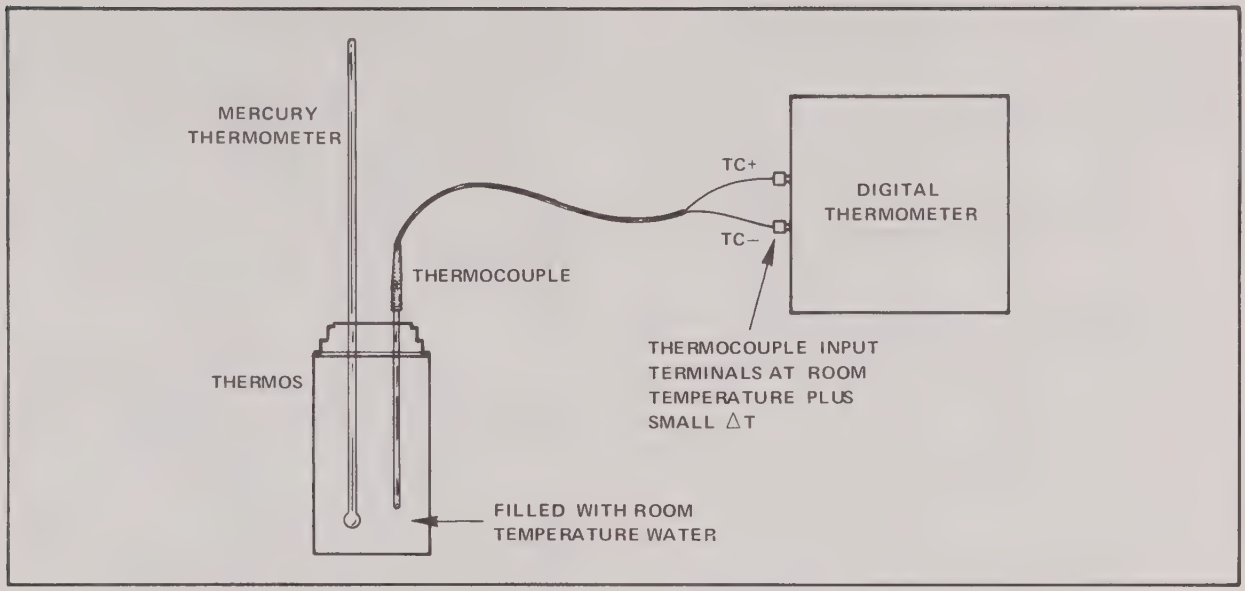


Figure 4-3. ROOM TEMPERATURE LAG BATH

Table 4-3. TEMPERATURE ACCURACY

TYPE	DIVIDER OUTPUT (mV dc)	°F DISPLAY LIMITS 90 DAY	°F DISPLAY LIMITS 1 YEAR	DIVIDER OUTPUT (mV dc)	°C DISPLAY LIMITS 90 DAY	°C DISPLAY LIMITS 1 YEAR
J	42.640	1390.5 to 1393.5	1390 to 1394	42.640	754.6 to 756.6	754.1 to 757.1
	2.288	110.5 to 113.5	110 to 114	2.288	43.4 to 45.4	42.9 to 45.9
	–1.643	–30 to –26	–30.5 to –25.5	–2.175	–45.9 to –42.9	–45.9 to –42.9
	–7.634	–310 to –306	–310.5 to –305.5	–7.344	–179.3 to –176.3	–179.3 to –176.3
K	52.789	2389.5 to 2394.5	2389 to 2395	49.638	1220.7 to 1223.7	1220.2 to 1224.2
	2.709	149.5 to 154.5	149 to 155	6.363	154.1 to 157.1	153.6 to 157.6
	–1.691	–50.5 to –45.5	–51 to –45	–1.691	–45.9 to –42.9	–46.4 to –42.4
	–5.713	–310.5 to –305.5	–311 to –305	–5.510	–179.3 to –176.3	–179.8 to –175.8
T	20.188	730.5 to 733.5	730 to 734	19.497	376.8 to 378.8	376.8 to 378.8
	0.879	70.5 to 73.5	70 to 74	0.8789	21.2 to 23.2	21.2 to 23.2
	–1.240	–30 to –26	–31.5 to –24.5	–2.009	–57.1 to –54.1	–57.6 to –53.6
	–5.421	–310 to –306	–311.5 to –304.5	–5.221	–179.3 to –176.3	–179.8 to –175.8
E	74.694	1790 to 1794	1789.5 to 1794.5	74.694	976.8 to 978.8	976.3 to 979.3
	2.694	110 to 114	109.5 to 114.5	2.694	43.4 to 45.4	42.9 to 45.9
	–1.897	–30 to –26	–31.5 to –24.5	–3.080	–57.1 to –54.1	–57.6 to –53.6
	–8.529	–310 to –306	–311.5 to –304.5	–8.209	–179.3 to –176.3	–179.8 to –175.8
R	20.951	3188 to 3196	3187 to 3197	20.951	1753.1 to 1757.1	1752.6 to 1758.6
	0.259	108 to 116	107 to 117	0.259	41.9 to 46.9	41.4 to 47.4
S	18.321	3148.5 to 3155.5	3147.5 to 3156.5	17.295	1642.4 to 1646.4	1641.4 to 1647.4
	0.262	109.5 to 114.5	107.5 to 116.5	0.262	42.2 to 46.4	41.4 to 47.4
B	13.585	3268.5 to 3275.5	3267.5 to 3276.5	13.585	1798 to 1802	1797.5 to 1802.5
	1.535	1028.5 to 1035.5	1027.5 to 1036.5	1.661	575.8 to 579.8	575.3 to 580.3
C	35.875	3977 to 3987	3977 to 3988	35.875	2191 to 2197	2191 to 2197
	1.276	187 to 197	187 to 198	.614	41 to 47	41 to 47

Table 4-4. REFERENCE-JUNCTION ACCURACY LIMITS

TYPE THERMOCOUPLE	°F	°C
J	±1.5°	±1.5°
K	±2.0°	±1.5°
T	±1.5°	±1.5°
E	±1.5°	±1.5°
R	±2.5°	±2.0°
S	±2.5°	±2.0°
C	±4.5°	±3.0°
The thermometer should read within the above limits for either the 90-day or 1-year check.		

b. Monitor the ambient temperature (room temperature) using a mercury thermometer near the back of the digital thermometer.

c. The digital thermometer will display the temperature of the internal reference junction. This temperature should not exceed the ambient temperature by more than 5° C (9° F).

d. Remove the short from the thermocouple input terminals.

e. This completes the test for internal temperature rise.

4-27. CALIBRATION

4-28. The thermometer should be calibrated every year or every 90 days, depending on the desired accuracy. Calibration should be performed also after the thermometer has been repaired or after the thermocouple linearizer (type-select) pcb has been changed.

4-29. Calibration of either the °F or °C scale, ensures the accuracy of both scales. Either scale can be verified after calibration by executing the accuracy portion of the Performance Test.

4-30. Interpolation of calibration setting for the °F scale is not necessary to obtain the specified performance accuracy. However, the °C scale requires interpolation of the calibration setting in order to obtain the specified performance. The following examples illustrate the difference.

4-31. °F example: For a K-type thermocouple, a voltage divider output of 52.789 mV is applied to the thermometer input. (See Table 4-5.) It is necessary only to set the calibration potentiometer to any setting that results in a digital display of 2392° F.

4-32. °C example: Calibration in °C is slightly more involved. For a K-type thermocouple, Table 4-5 shows that 49.638 mV are to be applied to the thermocouple input terminals. In order to calibrate to a required ±0.25°C of the specified 1222.2° C, first adjust the potentiometer for a display flicker from 1221 to 1222. This locates the 1221.5° C position of the potentiometer. (The thermometer internally "rounds up" .5, .6, .7, .8, and .9 values, and drops .1, .2, .3 and .4). Next, count the number of turns, X, of the potentiometer to reach a display flicker from 1222 to 1223. This locates the 1222.5° C position of the potentiometer. Turn the potentiometer back .3X turns to locate the 1222.2° C position of the pot.

4-33. B-type thermocouple calibration is different than that for other thermocouple types. A B-type thermocouple has no output at room temperature so does not require offset and reference-junction compensation for the equivalent thermocouple formed at the instrument input terminals. Therefore, to calibrate a B-type thermocouple, leave the RJD jumper in the operate position and execute only paragraphs 4-34, 4-35, 4-36 and 4-37, of the Calibration procedure; then reassemble the digital thermometer.

Table 4-5. FULL SCALE CALIBRATION

PROBE TYPE	°F		°C	
	DIVIDER OUTPUT (mV dc)	DISPLAY READING	DIVIDER OUTPUT (mV dc)	DISPLAY READING
J	+42.640	1392°F	+42.640	755.6°C
K	+52.789	2392°F	+49.638	1222.2°C
T	+20.188	732°F	+19.497	377.8°C
E	+74.694	1792°F	+74.694	977.8°C
R	+20.951	3192°F	+20.951	1755.6°C
S	+18.321	3152°F	+17.295	1644.4°C
B	+13.585	3272°F	+13.585	1800.0°C
C	+35.875	3982°F	+35.875	2194.4°C

4-34. Calibration Procedure

4-35. SET-UP FOR CALIBRATION

a. Complete the equipment connections shown in Figure 4-2, by doing the following:

1. Connect the 100:1 divider specified in Table 4-1.

2. Apply power to the calibrator and turn it on. Allow sufficient warm-up time to assure calibration-output-voltage accuracy.

b. Remove the thermometer from its case only for maintenance calibration or reference-junction adjustment. (See Paragraph 4-7.)

c. Locate the RJD jumper on the display pcb. Set it to the RJD position. (This defeats the reference-junction circuitry.)

d. Connect the voltage-divider output to the thermocouple input terminals.

e. Connect a short length of copper wire between the thermocouple input terminals.

f. Set the TEMP-scale jumper to °F or °C.

4-36. ZERO ADJUSTMENT

a. Adjust C17 to obtain a steady or flashing 0 or –0 for the Celsius scale, or to obtain a steady 32 for the Fahrenheit scale.

4-37. FULL SCALE ADJUSTMENT

a. Determine the thermocouple compatible with the thermometer. The markings on the plug-in linearizer (type-select) pcb indicate the thermocouple type. (See Figure 4-1.) The instrument will have to be removed from its case to see the linearizer pcb. (See Paragraph 4-7.)

b. Remove the short and connect the 100:1 divider output to the thermocouple input terminals. Match polarity.

c. Refer to Table 4-5 and set the calibrator output to obtain the voltage divider output specified for the compatible thermocouple type, for the degree scale being used.

d. Adjust the FULL-SCALE CAL potentiometer, R6 (Figure 4-1), to obtain the temperature display specified in Table 4-5.

e. This completes the calibration procedure for B-type thermocouples only.

4-38. OFFSET ADJUSTMENT

a. Set the RJD jumper to the operate position.

b. Remove the divider leads from the thermocouple input terminals.

c. Short the thermocouple input terminals with a small piece of copper wire.

d. Remove the 100:1 divider from the calibrator output.

e. Set the calibrator to the 10V dc range.

f. Adjust the calibrator output to .5785V dc.

CAUTION

Be sure the voltage output of the calibrator is .5785V dc before proceeding to the next step. Improper voltage could damage the digital thermometer. Do not use the divider to obtain .5785V dc because the output impedance will create an error.

g. Connect the positive lead from the calibrator to the positive thermocouple input terminal.

h. Connect the negative lead from the calibrator to Test Point 2. (TP2(–) in Figure 4-1).

i. Adjust the OFFSET CAL potentiometer, R4, for a temperature display of 77° F or 25° C ± ¼° C. (See Paragraph 4-30 on interpolation.)

j. Remove the calibrator output from the plus input terminal and TP2.

k. Remove the short at the thermocouple input terminals.

l. If the thermometer is being calibrated on a routine calibration cycle, or because of thermocouple type-change, this completes calibration. Reassemble the thermometer.

m. If the thermometer is being recalibrated because of repair or if reference-junction adjustment is desired, proceed with paragraph 4-39.

4-39. REFERENCE-JUNCTION ADJUSTMENT

a. Connect a compatible thermocouple probe to the input terminals. Match polarity. J, K, T and E thermocouples have a red wire for the negative lead. Refer to the manufacturer for R, S, and C color coding.

b. Place the thermocouple in a room-temperature lag bath. (See Figure 4-3 for an illustration of lag-bath construction.)

c. Use an accurate mercury thermometer to monitor the temperature of the lag-bath. (See Table 4-1.)

d. Adjust the REFERENCE-JUNCTION CAL potentiometer, R15, to obtain a display that agrees with the lag-bath temperature.

e. Remove the thermocouple and reassemble the digital thermometer.

4-40. REFERENCE-JUNCTION BIAS-RESISTOR SELECTION

4-41. If the reference-junction transistor Q7 is replaced, then the reference-junction bias resistor R14 must also be replaced. This is a selected resistor which must be matched to Q7. To select the resistor:

a. Complete the calibration paragraphs 4-35 through 4-38.

b. Connect a compatible thermocouple probe to the input terminals. Match polarity. J, K, T and E thermocouples have a red wire for the negative lead. Refer to the manufacturer for R, S and C color coding.

c. Center the reference-junction pot R15.

d. Connect a decade resistance box that has ranges including 1K, 10K, and 100K, in place of the reference-junction bias resistor R14. (See Table 4-1.)

e. Place the thermocouple in a room-temperature lag bath. (See Figure 4-3 for an illustration of lag-bath construction.)

f. Use an accurate mercury thermometer to monitor the temperature of the lag bath. (See Table 4-1.)

g. Adjust the decade resistance box for the value from Table 4-6 that causes the thermometer to read closest to lag-bath temperature. This will be the value of the reference-junction bias resistor R14.

h. Disconnect the decade box and install the selected R14.

Table 4-6. BIAS RESISTOR VALUES

VALUE	JOHN FLUKE PART NUMBER	VALUE	JOHN FLUKE PART NUMBER
49.9K	268821	90.9K	223537
52.3K	237248	100K	248807
54.9K	271353	110K	234708
57.6K	289116	124K	288407
60.4K	291419	140K	289439
63.4K	235382	162K	375998
68.1K	236828	191K	375923
73.2K	237222	237K	288373
78.7K	289058	309K	235283
84.5K	229492	562K	235358

i. Adjust the reference junction potentiometer so that the thermometer reading matches the lag-bath temperature.

j. Remove the thermocouple and reassemble the digital thermometer.

k. This completes the selection of R14. This also completes the calibration of the reference junction.

4-42. CALIBRATION TECHNIQUES

4-43. Calibration of the reference junction (R15) can be performed using any type of thermocouple except B-type. Once the reference junction has been calibrated for one type of thermocouple, it will be in calibration for use with any other thermocouple type. (Type B thermocouples do not use the reference junction due to their low output levels at room temperature.) Therefore, a calibration facility that maintains several digital thermometers which are configured for different thermocouple types, requires only one thermocouple probe and its corresponding linearizer (type-select) pcb in order to calibrate the reference junction of all of the instruments. A K-type thermocouple and linearizer pcb are recommended. This technique is especially useful in the repair of an instrument that is normally used with a C-type thermocouple. C types are expensive, the wire is brittle and the accuracy is relatively poor. The calibration facility can use the above technique rather than to stock C-type probes. The following procedure illustrates:

a. Calibrate the repaired thermometer with the K-type thermocouple and K-type linearizer pcb installed. Follow paragraphs 4-35 through 4-39. This calibrates the reference junction.

b. Change the thermometer to another type of thermocouple by changing the linearizer pcb and repeating paragraphs 4-35 through paragraph 4-38 only. These paragraphs do not require the actual thermocouple probe, but accomplish full-scale calibration for the non-K-type probe without disturbing the reference-junction calibration just set in a. above.

4-44. Thermocouple Accuracy Relating to the Reference-Junction Calibration Technique

4-45. The thermocouples specified in the list of calibration equipment meet specifications of ANSI Standard C96.1. The specifications for these probes can be as much as 4°F absolute error at or near room temperature. The

first conclusion is that those probes could produce a calibration error of ±4° F when used for calibrating the reference junction. This is an erroneous conclusion. Figure 4-3 illustrates the set-up for calibration. Figure 4-4A illustrates the reference-junction compensation circuitry and Figure 4-4B illustrates the equivalent thermocouple circuit formed by the connection of the thermocouple to the input of the instrument. Note that in Figure 4-4B, the two thermocouple junctions formed at the input of the instrument (plus thermocouple wire (+TC) to the plus input terminal and the minus thermocouple wire (–TC) to the minus input terminal) can be represented as a single junction of +TC to –TC whose temperature is that of the input terminals of the instrument.

4-46. The reference-junction circuitry senses the terminal temperature and generates a voltage that is equal to the voltage generated by the equivalent thermocouple formed at the input terminals referenced to ice point (See Figure 4-4A). For example, suppose the input terminals of the instrument and the attached probe are at the same temperature of 25° C. Since the thermocouple output voltage is proportional to the temperature between the two junctions, the output is zero volts. The reference-junction circuitry supplies a compensating voltage to the instrument such that the instrument will read 25° C. When calibrating the reference junction using the lag-bath technique, the reference junction is adjusted so that the instrument reads the lag-bath temperature. In using the lag-bath technique, there is only a small temperature difference, ΔT, between the thermocouple junction in the probe and the equivalent thermocouple junction formed at the input terminals of the instrument. The voltage output across the thermocouple circuit is proportional to the temperature difference, ΔT, between the two junctions. Hence, since ΔT is small, there is a small input voltage applied to the input of the instrument. This small input voltage will represent ΔT accurately to within less than .1° F. Therefore, when the reference junction is calibrated so that the instrument reads lag-bath temperature, the error introduced by the thermocouple will be less than .1° F.

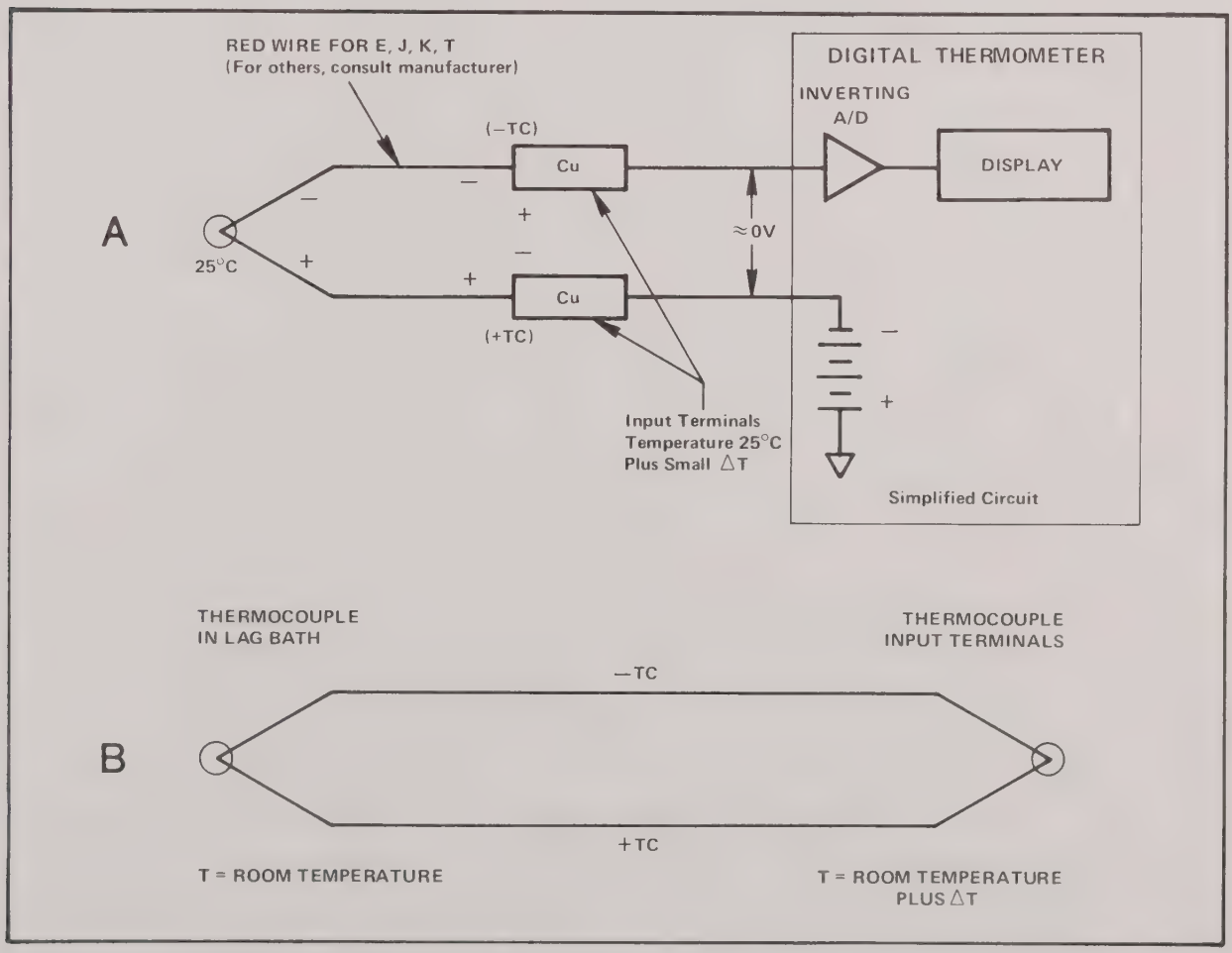


Figure 4-4. REFERENCE-JUNCTION COMPENSATION CIRCUITRY

4-47. Over-all Accuracy

4-48. As explained above in 4-43, the instrument will read very accurately around room temperature (See paragraph 403) but as the measured temperature increases or decreases from room temperature, the amount of thermocouple output deviation from NBS Standard 125, becomes the limiting factor in the accuracy of the instrument. If the thermocouple is in error by +4° F, at 900° F the display will be +4° F higher than if the thermocouple conformed perfectly to NBS Standard 125. Error specifications for the instrument do not include thermocouple probe inaccuracies. Those errors must be added to the instrument error in order to obtain an over-all accuracy figure.

4-49. TROUBLESHOOTING

4-50. A troubleshooting guide for the thermometer is given in Table 4-7. The guide is a simplified decision table and is recommended for use in isolating a problem to a functional circuit group. Details necessary to troubleshoot a fault in a functional circuit group can be derived from Section 3 Theory of Operation and Section 8 Schematic Diagrams.

Table 4-7. TROUBLESHOOTING GUIDE

STEP	INSTRUCTION	IF YES GO TO	IF NO GO TO	GO TO
1	Energize the unit and connect a short across the thermocouple input terminals.			2
2	Does the display light?	16	3	
3	Is the power fuse blown?	4	5	
4	Replace fuse.			2
5	Are all power supply voltages present; +5, +6.8, +15 and −12V dc?	7	6	
6	Repair power supply.			2
7	Are Strobe Out pulses present at pins 9, 10, 11 and 12 of U4. (Use logic common as reference.)?	10	8	
8	Is crystal operating?	10	9	
9	Replace crystal.			2
10	Are display drivers functioning?	13	11	
11	Is output data present at pins 4, 5, 6 and 7 of U4?	12	13	
12	Replace display drivers as necessary.			2
13	Are $\overline{\Delta 2}$, AZ, INT, DE+ or DE−, and CM present at U4?	14	15	
14	Display PCB defective. Repair as necessary.			2
15	U4 is defective. Replace.			2
16	Does display read approximate ambient temperature?	21	17	
17	Refer to Section 3 of this manual and use a scope to check for the presence of the waveforms shown in Figure 3-2.			18
18	Are all waveforms correct?	20	19	
19	Perform the necessary repairs to the analog circuit.			17
20	Calibrate the thermometer.			21
21	End. Thermometer is functional.			

PERFORMANCE TEST CHECKLIST

Fluke Model 2160A Digital Thermometer

Serial Number_____
Tested By:_____
Date:_____

°F VERIFICATION TABLE (TEMPERATURE ACCURACY)

PROBE TYPE	NOMINAL TEMPERATURE °F	90 DAY			1 YEAR		
		MIN.	ACTUAL	MAX.	MIN.	ACTUAL	MAX.
J	1392	1390.5	_____	1393.5	1390	_____	1394
	112	110.5	_____	113.5	110	_____	114
	−28	−30	_____	−26	−30.5	_____	−25.5
	−308	−310	_____	−306	−310.5	_____	−305.5
K	2392	2389.5	_____	2394.5	2389	_____	2395
	152	149.5	_____	154.4	149	_____	155
	−48	−50.5	_____	−45.5	−51	_____	−45
	−308	−310.5	_____	−305.5	−311	_____	−305
T	732	730.5	_____	733.5	730	_____	734
	72	70.5	_____	73.5	70	_____	74
	−28	−30	_____	−26	−31.5	_____	−24.5
	−308	−310	_____	−306	−311.5	_____	−304.5
E	1792	1790	_____	1794	1789.5	_____	1794.5
	112	110	_____	114	109.5	_____	114.5
	−28	−30	_____	−26	−31.5	_____	−24.5
	−308	−310	_____	−306	−311.5	_____	−304.5
R	3192	3188	_____	3196	3187	_____	3197
	112	108	_____	116	107	_____	117
S	3152	3148.5	_____	3155.5	3147.5	_____	3156.5
	112	109.5	_____	114.5	107.5	_____	116.5
B	3272	3268.5	_____	3275.5	3267.5	_____	3276.5
	1032	1028.5	_____	1035.5	1027.5	_____	1036.5
C	3982	3977	_____	3987	3977	_____	3988
	192	187	_____	197	187	_____	198

Line Voltage Regulation _____ Passed ( ) Failed ( )

Accuracy Test _____ See Verification Tables

°F VERIFICATION TABLE (REFERENCE JUNCTION ACCURACY)

PROBE TYPE	90-Day or 1-Year	
	Deviation Error From Room-Temperature Lag Bath	
	Maximum	Actual
J	±1.5°	
K	±2.0°	
T	±1.5°	
E	±1.5°	
R	±2.5°	
S	±2.5°	
C	±4.5°	

PERFORMANCE TEST CHECKLIST, Cont.

Overload
- Overrange . . . . . Passed ( ) Failed ( )
- Open Circuit . . . . . Passed ( ) Failed ( )

Internal Temperature Rise . . . . . <5°C (9°F) above ambient

°C VERIFICATION TABLE (TEMPERATURE ACCURACY)

PROBE TYPE	NOMINAL TEMPERATURE °C	90 DAY			1 YEAR		
		MIN.	ACTUAL	MAX.	MIN.	ACTUAL	MAX.
J	755.4	754.6		756.6	754.1		757.1
	44.4	43.4		45.4	42.9		46.9
	−44.4	−45.9		−42.9	−46.9		−42.9
	177.8	−179.3		−176.3	−179.3		−176.3
K	1222.2	1220.7		1223.7	1220.2		1224.2
	155.6	154.1		157.1	153.6		157.6
	−44.4	−45.9		−42.9	−46.4		−42.4
	−177.8	−179.3		−176.3	−179.8		−175.8
T	377.8	376.8		378.8	376.8		378.8
	22.2	21.2		23.2	21.2		23.2
	−55.6	−57.1		−54.1	−57.6		−53.6
	−177.8	−179.3		−176.3	−179.8		−175.8
E	977.8	976.3		979.3	975.8		979.8
	44.4	42.9		45.9	42.4		46.4
	−55.6	−57.1		−54.1	−57.6		−53.6
	−177.8	−179.3		−176.3	−179.8		−175.8
R	1755.6	1753.1		1758.1	1752.6		1758.6
	44.4	41.9		46.9	41.4		47.4
S	1644.4	1642.4		1646.4	1641.4		1647.4
	44.4	42.4		46.4	41.4		47.4
B	1800	1798		1802	1797.5		1802.5
	577.8	575.8		579.8	575.3		580.3
C	2194.4	2191		2197	2191		2197
	44.4	41		47	41		47

°C VERIFICATION TABLE (REFERENCE JUNCTION ACCURACY)

PROBE TYPE	90-Day or 1-Year	
	Deviation Error From Room-Temperature Lag Bath	
	Maximum	Actual
J	±1.5°	
K	±1.5°	
T	±1.5°	
E	±1.5°	
R	±2.0°	
S	±2.0°	
C	±3.0°	

Section 5

Lists of Replaceable Parts

REFERENCE DESIGNATOR	ASSEMBLY NAME/NUMBER	PART NO.	PAGE
	Digital Thermometer, Final Assembly (2160A)	———	5-3
A1	Thermometer Assembly		
	100V ac (2160A-4010T-2)	420737	5-4
	115V ac (2160A-4010T)	420703	5-4
	230V ac (2160A-4010T-3)	420752	5-4
A1A1	Thermometer PCB Assembly (2160A-4010)	415604	5-5
A1A2	Display PCB Assembly (2160A-4021)	443499	5-8
A2	Type Select PCB Assembly	———	5-9

5-1. INTRODUCTION

5-2. This section contains an illustrated parts breakdown of the instrument. Components are listed alpha-numerically by assembly. Electrical components are listed by reference designation and mechanical components are listed by item number. Each listed part is shown in an accompanying illustration.

5-3. Parts lists include the following information:

a. Reference Designation or Item Number.

b. Description of each part.

c. Fluke Stock Number.

d. Federal Supply Code for Manufacturers. (See Appendix A for Code-to-Name list.)

e. Manufacturer's part Number or Type.

f. Total Quantity per assembly or component.

g. Recommended Quantity: This entry indicates the recommended number of spare parts necessary to support one to five instruments for a period of two years. This list presumes an availability of common electronic parts at the maintenance site. For maintenance for one year or more at an isolated site, it is recommended that at least one of each assembly in the instrument be stocked. In the case of optional subassemblies, plug-ins, etc. that are not always part of the instrument, or are deviations from the basic instrument mode, the REC QTY column lists the recommended quantity of the item in that particular assembly.

h. Use Code is provided to identify certain parts that have been added, deleted or modified during production of the instrument. Each part for which a use code has been assigned may be identified with a particular instrument serial number by consulting the Use Code Effectivity, paragraph 5-7.

5-4. HOW TO OBTAIN PARTS

5-5. Components may be ordered directly from the manufacturer by using the manufacturer's part number, or from the John Fluke Mfg. Co., Inc. factory or authorized representative by using the FLUKE STOCK NUMBER. In the event the part you order has been replaced by a new or improved part, the replacement will be accompanied by an explanatory note and installation instructions, if necessary.

5-6. To ensure prompt and efficient handling of your order, include the following information.

a. Quantity

b. FLUKE Stock Number

c. Description

d. Reference Designation or Item Number

e. Printed Circuit Board Part Number

f. Instrument model and Serial number

5-7. USE CODE EFFECTIVITY LIST

USE CODE	SERIAL NUMBER EFFECTIVITY
A	0123 to 50000
B	50000 and on.

Indicates MOS device which may be damaged by static discharge.

FINAL ASSEMBLY, 2160A

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	DIGITAL THERMOMETER FINAL ASSEMBLY 2160A						
A1	Thermometer Assembly				1		
	100V ac (2160A-4010T-2)	420737	89536	420737			
	115V ac (2160A-4010T)	420703	89536	420703			
	230V ac (2160A-4010T-3)	420752	89536	420752			
A2	Type Select PCB Assembly				1		
	One-of-eight possible type select pcb assemblies is supplied with the unit.						
	R Type Select PCB Assembly (2160A-4012)	415612	89536	415612			
	S Type Select PCB Assembly (2160A-4013)	415620	89536	415620			
	B Type Select PCB Assembly (2160A-4014)	415638	89536	415638			
	C Type Select PCB Assembly (2160A-4015)	415646	89536	415646			
	J Type Select PCB Assembly (2160A-4016)	415653	89536	415653			
	K Type Select PCB Assembly (2160A-4017)	415661	89536	415661			
	T Type Select PCB Assembly (2160A-4018)	415927	89536	415927			
	E Type Select PCB Assembly (2160A-4019)	415935	89536	415935			
1	Bezel, panel meter	394502	89536	394502	1		
2	Case, extrusion	415505	89536	415505	1		
3	Decal, front-panel	416768	89536	416768	1		
4	Decal, model	416784	89536	415784	1		
5	Decal, serial-number	416776	89536	416776	1		
6	Decal, thermocouple-type	416792	89536	416792	1		
7	Insulator	415513	89536	415513	1		
8	Lens, plastic	413716	89536	413716	1		
9	Pawl, cast	407437	89536	4107437	1		

A1 THERMOMETER ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A1	THERMOMETER ASSEMBLY				REF		
	100V ac (2160A-4010T-2)	420737	89536	420737			
	115V ac (2160A-4010T)	420703	89536	420703			
	230V ac (2160A-4010T-3)	420752	89536	420752			
A1A1	Thermometer PCB Assembly (2160A-4010)	415604	89536	415604	1		
A1A2	Display PCB Assembly (2160A-4021)	443499	89536	443499	1		
T1	Transformer, power				1		
	100V ac (2160A-6512)	421032	89536	421032			
	115V ac (2160A6510)	421057	89536	421057			
	230V ac (2160A-6511)	421040	89536	421040			
U4	LSI Digital IC, P-MOS ⊗	403527	70203	C-10186	1	1	
	Cord and plug, ac line	102822	70903	PH-70	1	1	
	Cord and plug, ac line (230V)	343780	89536	343780	1		
	Panel, rear	413799	89536	413799	1		

A1A1 THERMOMETER PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A1A1	**THERMOMETER PCB ASSEMBLY (2160A-4010)** **Figure 8-1**	415604	89536	415604	REF		
C1	Cap, cer, .01 uF ±20%, 3kV	266320	56289	41C301A2	1		
C3, C4	Cap, elect, 100 uF −10/+100 25 V	416982	56289	503D107 CG	1	1	
C5	Cap, elect, 4000 uF +100/−10%, 10V	330761	25088	B41010-4700/10	1	1	
C6, C7, C14, C19	Cap, Ta, 10 uF ±20%, 20V	330662	56289	196D106X0020 JA1	4		
C8	Cap, mica, 100 pF ±1%, 500V	226126	71234	DM15F100F	1		
C9	Cap, mylar, 0.47 uF ±10%, 100V	369124	73445	C280MA/H470K	1		
C10	Cap, disc, 100 pF ±10%, 1kV	105593	71590	DD101	1		
C11	Cap, Ta, 2.2 uF ±10%, 15V	364216	56289	196D222X9015 H1A	1		
C12	Cap, cer, .025 uF ±20%, 100V	168435	56289	C023B101H253 M	1		
C13	Cap, polypro, 0.47 uF ±10%, 50V	363085	01281	JF86	1		
C15	Cap, cer, 2700 pF ±20%, 100V	362889	72982	8121-A100-W5R 272M	1		
C16, C20	Cap, cer, 1000 pF ±10%, 500V	357806	56289	C106B102G102K	2		
C17	Cap, var, 0.25 - 1.5 pF, 2kV	218206	72982	530-000	1	1	
C18	Cap, cer, 1 pF ±0.25 pF, 100V	436477	72982	8101-A100-C0G-1 09G	1		
CR1, CR2,	Diode, bridge rectifier	418582	50044	VM08	2	1	
F1	Fuse, slo-blo, 1/16A	163030	71400	MDL1-16	1	5	
J1	Connector, female, 18-pin	435024	00779	583773-8	1		
Q1 thru Q6, Q8, Q9, Q12, Q14	Xstr, J-FET, N-channel	343830	89536	343830	10	2	
Q7	Xstr, Si, NPN	329698	07263	2N2484	1	1	

A1A1 THERMOMETER PCB ASSEMBLY (Cont.)

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
Q10	Xstr, FET, dual N-channel	439703	89536	439703	1	1	
Q11, Q15,	Xstr, Si, NPN	218396	04713	2N3904	2	1	
Q13	Xstr, FET, dual N-channel	379321	89536	379321	1	1	
R1	Res, comp, 430 ±5%, ½W	109058	01121	EB4315	1		
R3	Res, mf, 15.8k ±1%, 1/8W	293688	91637	MFF1-81582F	1		
R4, R6	Res, var, 25k ±20%, ½W	285213	71450	190PC253B	2	1	
R5	Res, mf, 261k ±1%, 1/8W	257535	91637	MFF1-82613F	1		
R7	Res, mf, 187k ±1%, 1/8W	257469	91637	MFF1-81873F	1		
R8	Res, mf, 2k ±0.1%, 1/8W	340174	91637	MFF1-82001B	1		
R9	Res, mf, 1k ±0.1%, 1/8W	340380	91637	MFF1-81001B	1		
R10	Res, comp, 47k ±5%, 1W	150219	01121	GB4735	1		
R11, R29	Res, comp, 1M ±5%, ¼W	182204	01121	CB1055	2		
R12	Res, mf, 26.7k ± .1%, 1/8W	344465	91637	MFF1-82672B	1		
R13	Res, mf, 150k ±1%, 1/8W	241083	91637	MFF1-81503F	1		
R15	Res, var, 50k ±20%, ½W	330688	71450	190PC504B	1	1	
R16, R17	Res, mf, 14.7k ±1%, 1/8W	226225	91637	MFF1-81472F	2		
R18	Res, comp, 470 ±5%, ¼W	147983	01121	CB4715	1		
R20	Res, mf, 28.7k ±1%, 1/8W	235176	91637	MFF1-82872F	1		
R21	Res, mf, 61.9k ±1%, 1/8W	237230	91637	MFF1-86192F	1		
R22	Res, mf, 19.1k ±1%, 1/8W	234963	91637	MFF1-81912F	1		
R23	Res, mf, 1k ±1%, 1/8W	168229	91637	MFF1-81001F	1		
R24, R25	Res, mf, 82.5k ±1%, 1/8W	246223	91637	MFF1-88252F	2		
R26	Res, comp, 680k ±5%, ¼W	188433	01121	CB6845	1		
R27	Res, comp, 100 ±5%, ¼W	147926	01121	CB1015	1		
R28, R33	Res, comp, 220k ±5%, ¼W	160937	01121	CB2245	2		

A1A1 THERMOMETER PCB ASSEMBLY (Cont.)

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
R30, R32	Res, comp, 20k ±5%, ¼W	221614	01121	CB2035	2		
R34 thru R37	Res, comp, 27k ±5%, ¼W	148148	01121	CB2735	4		
U1	IC, dual opnl ampl	404087	49956	RC4739DP	1	1	
U2	IC, opnl ampl	352195	49956	RC311DN	1	1	
U5	IC, TTL, bcd-to-7 segment decoder driver	340109	01295	SN7447	1	1	
U6	IC, C-MOS, Hex Buffer/Inverter ⊗	381830	02735	CD4050AE	1	1	
U8	IC, linear, voltage regulator, +15V	413187	12040	LM340T-18	1	1	
U9	IC, linear, voltage regulator, −12V	381665	04713	MC7912CP	1	1	
VR1	Diode, zener, 6.4V ±2%	393579	04713	1N4567	1	1	
VR2	Diode, zener, 6.8V	260695	07910	1N754A	1	1	
Y1	Crystal, 400 kHz	403352	89536	403352	1		
1	Connector, post pin	267633	00779	86144-1	8		
2	Header	417030	00779	87230-8	1		
3	Isothermal Block						
	Insulator	415695	89536	415695	1		
	Plate, terminal, neg	415687	89536	415687	1		
	Plate, terminal, pos	415679	89536	415679	1		
4	Socket, IC, 40-pin	418988	91506	340-AG37D	1		

A1A2 DISPLAY PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A1A2	**DISPLAY PCB ASSEMBLY (2160A-4021)** **Figure 8-3**	443499	89536	443499	REF		
DS1, DS2	LED, dual 7-segment character display	419051	29083	MAN 6610	2	1	A
DS3	LED, 7-segment character display	407874	29083	MAN 4610	1	1	A
DS1 thru DS5	LED, 7-segment, numeric display	418012	28480	5082-7651	5	1	B
Q1 thru Q4	Xstr, Si, Darlington NPN	381798	04713	MPS A-13	4	1	
R1	Res, comp 91 ±5%, 1/4W	221887	01121	CB9105	1		
U1	IC, res network, 60Ω	344069	89536	344069	1	1	

A2 TYPE SELECT PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A2	**TYPE SELECT PCB ASSEMBLY**				REF		
	Figure 8-5						
	R Type (2160A-4012)	415612	89536	415612			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 324 ±1%, 1/8W	423780	91637	MFF1-83240F	1		
R2	Res, mf, 69.5 ±0.1%, 1/8W	423756	91637	MFF1-869R5B	1		
	S Type (2160A-4013)	415620	89536	415620			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 324 ±1%, 1/8W	423780	91637	MFF1-83240F	1		
R2	Res, mf, 70 ±0.1%, 1/8W	423764	91637	MFF1-8A700F	1		
	B Type (2160A-4014)	415638	89536	415638			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 143 ±1%, 1/8W	423699	91637	MFF1-81430F	1		
	C Type (2160A-4015)	415646	89536	415646			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 590 ±1%, 1/8W	446625	91637	MFF1-85910F	1		
R2	Res, mf, 164.3 ±0.1%, 1/8W	424564	91637	MFF1-8164R38	1		
	J Type (2160A-4016)	415653	89536	415653			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 10.7k ±1%, 1/8W	423681	91637	MFF1-81072F	1		
R2	Res, mf, 619 ±0.1%, 1/8W	423715	91637	MFF1-86190B	1		
	K Type (2160A-4017)	415661	89536	415661			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 3.74k ±1%, 1/8W	260547	91637	MFF1-83741F	1		
R2	Res, mf, 481.4 ±0.1%, 1/8W	423723	91637	MFF1-8481R4B	1		

A2 TYPE SELECT PCB ASSEMBLY (Cont.)

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	T Type (2160A-4018)	415927	89536	415927			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 3.74k ±1%, 1/8W	260547	91637	MFF1-83741F	1		
R2	Res, mf, 483.7 ±0.1%, 1/8W	423731	91637	MFF1-8483R7B	1		
	E Type (2160A-4019)	415935	89536	415935			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 53.6k ±1%, 1/8W	291401	91637	MFF1-85362F	1		
R2	Res, mf, 732 ±0.1%, 1/8W	423749	91637	MFF1-87320B	1		

Section 6
Option & Accessory Information

6-1. INTRODUCTION

6-2. This section of the manual contains information concerning the Options and Accessories available for use with the Model 2160A Digital Thermometer. The first portion of this section provides a brief description of each option and accessory. The depth of detail is intended to give the prospective user an adequate first acquaintance with the features and capabilities of each. Detailed information concerning specifications, operating instructions, maintenance, list of replaceable parts, and schematics is supplied separately with some options and accessories, and is designed to comprise the second portion of this section. Unique page and paragraph numbering is assigned to each of the add-on descriptions to allow separation into easily identifiable subsections. The material is prepunched (T-punched) to permit insertion without disassembling the manual. Table 6-1 lists the available options and accessories and defines the manner in which each is documented.

6-3. THERMOCOUPLE PROBES

6-4. Three types of thermocouple probe assemblies (J, K and T) are available from Fluke for use with the 2160A. See Table 6-1. Each thermocouple is enclosed in a 6-inch x 1/8 inch iconel sheath, and includes a heavy duty transition splice and spring. See Figure 6-1. The thermocouple junction is grounded to the sheath, and 36-inch trimmed leads are included on all units. Refer to the Tables under Specifications in Section 1 of this manual for the temperature ranges recommended for each thermocouple type.

6-5. RACK MOUNTING PANELS

6-6. Three rack-mounting panels are available for mounting the 2160A in a standard 19-inch equipment rack. The panels, listed in Table 6-1, provide the option of mounting either one, two or three units. Panel mounting instructions for the 2160A are given in Section 2 of this manual.

Table 6-1. 2160A OPTIONS, ACCESSORIES AND DOCUMENTATION SOURCES

MODEL OR OPTION NO.	DESCRIPTION	DOCUMENTATION SUPPLIED	
		WITH UNIT	HERE IN
P20J	J-Type TC Probe		●
P20K	K-Type TC Probe		●
P20T	T-Type TC Probe		●
2160A-7031	Rack Mtg. Panel, 1 unit		●
2160A-7032	Rack Mtg. Panel, 2 units		●
2160A-7033	Rack Mtg. Panel, 3 units		●
2160A-7016	J-Type Select PCB		●
2160A-7017	K-Type Select PCB		●
2160A-7019	E-Type Select PCB		●
2160A-7018	T-Type Select PCB		●
2160A-7012	R-Type Select PCB		●
2160A-7013	S-Type Select PCB		●
2160A-7014	B-Type Select PCB		●
2160A-7015	C-Type Select PCB		●
2160A-7022	Interface Cable		●
2161A	Multipoint Selector	○	
2162A	Digital Comparator	○	
–02	Digital Output Unit	○	
–04	Analog Output Unit	○	

○ = T-punched for insertion in Section 6 of this manual
● = Not T-punched

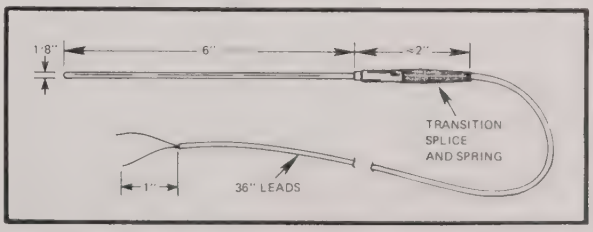


Figure 6-1. P20 SERIES THERMOCOUPLE PROBES

6-7. TYPE SELECT PCB's

6-8. A series of plug-in type select pcb's are available as accessories to allow the thermocouple compatibility of the 2160A to be changed by the user. The available pcb's are listed in Table 6-1, and the instructions necessary to interchange pcb's in the 2160A are given in Section 2 of this manual under Thermocouple Compatibility. Only one of the pcb's can be installed in the 2160A at any given time.

6-9. MODEL 2161A MULTIPOINT SELECTOR

6-10. The Model 2161A Multipoint Selector is a panel-mounting, manually-switched selector that allows 1-of-10 thermocouple probes (all of the same type) to function as the thermocouple input to the 2160A. When more than 10 inputs are involved, 2 or more 2161A's can be stacked in either a serial or parallel configuration.

6-11. MODEL 2162A DIGITAL COMPARATOR

6-12. The Model 2162A Digital Comparator is a panel-mounting, manually-set, single-limit comparator. Front-panel, thumb-wheel switches provide for the selection of high or low ($>$ or $\leqslant$), polarity and four limit digits. The resolution of the 2162A is $\pm 1^{\circ}$. A cable on the rear of the 2162A attaches to the back of the 2160A to provide the 2162A with both operating voltage and display data. When an out-of-limit reading occurs at the 2160A, the 2162A generates both a visual and an electrical indication, i.e., a front-panel LED is lit and a contact closure occurs. The contact closure is accessible through the 2162A's rear panel, and is electrically isolated from both the 2160A and the 2162A. Two 2162A's can be connected in parallel for multiple limit requirements.

6-13. DIGITAL OUTPUT UNIT, OPTION –02

6-14. The Digital Output Unit (Option –02) is a field installable pcb that mounts on the interior of the 2160A and provides a digital output which is equivalent to the displayed measurement data. The digital output is positive-true, TTL compatible and is presented in bcd, character-parallel format. All displayed characters are represented at the output. Output data is solicited by an External Trigger input and valid data is ensured by Busy and $\overline{\text{Busy}}$ outputs.

6-15. External connections to the Digital Output Unit are made through a 34-pin cable which is supplied with the pcb.

6-16. ANALOG OUTPUT UNIT, OPTION –04

6-17. The Analog Output Unit is a field installable pcb assembly which provides the 2160A with a rear-panel analog output voltage proportional to the displayed measurement data. The output voltage is electrically isolated from the 2160A and covers a voltage range of –0.4 to +4V dc. Automatic polarity sensing is provided for both °C and °F measurements to ensure that the polarity of the output voltage agrees with the displayed polarity. Since the analog output terminals are isolated from the 2160A, the output voltage is referenced to the low terminal of the external recording device (voltmeter, strip-chart recorder, etc.).

6-18. External connections to the Analog Output Unit are made through a connector and cable which is supplied with the pcb.

Section 7

General Information

7-1. This section of the manual contains generalized user information as well as supplemental information to the List of Replaceable Parts contained in Section 5.

List of Abbreviations and Symbols

A or amp	ampere
ac	alternating current
af	audio frequency
a/d	analog-to-digital
assy	assembly
AWG	american wire gauge
B	bel
bcd	binary coded decimal
°C	Celsius
cap	capacitor
ccw	counterclockwise
cer	ceramic
cermet	ceramic to metal(seal)
ckt	circuit
cm	centimeter
cmrr	common mode rejection ratio
comp	composition
cont	continue
crt	cathode-ray tube
cw	clockwise
d/a	digital-to-analog
dac	digital-to-analog converter
dB	decibel
dc	direct current
dmm	digital multimeter
dvm	digital voltmeter
elect	electrolytic
ext	external
F	farad
°F	Fahrenheit
FET	Field-effect transistor
ff	flip-flop
freq	frequency
FSN	federal stock number
g	gram
G	giga (10^9)
gd	guard
Ge	germanium
GHz	gigahertz
gmv	guaranteed minimum value
gnd	ground
H	henry
hd	heavy duty
hf	high frequency
Hz	hertz
IC	integrated circuit
if	intermediate frequency
in	inch(es)
intl	internal
I/O	input/output
k	kilo (10^3)
kHz	kilohertz
kΩ	kilohm(s)
kV	kilovolt(s)
lf	low frequency
LED	light-emitting diode
LSB	least significant bit
LSD	least significant digit
M	mega (10^6)
m	milli (10^{-3})
mA	milliampere(s)
max	maximum
mf	metal film
MHz	megahertz
min	minimum
mm	millimeter
ms	millisecond
MSB	most significant bit
MSD	most significant digit
MTBF	mean time between failures
MTTR	mean time to repair
mV	millivolt(s)
mv	multivibrator
MΩ	megohm(s)
n	nano (10^{-9})
na	not applicable
NC	normally closed
(-) or neg	negative
NO	normally open
ns	nanosecond
opnl ampl	operational amplifier
p	pico (10^{-12})
para	paragraph
pcb	printed circuit board
pF	picofarad
pn	part number
(+) or pos	positive
pot	potentiometer
p-p	peak-to-peak
ppm	parts per million
PROM	programmable read-only memory
psi	pound-force per square inch
RAM	random-access memory
rf	radio frequency
rms	root mean square
ROM	read-only memory
s or sec	second (time)
scope	oscilloscope
SH	shield
Si	silicon
serno	serial number
sr	shift register
Ta	tantalum
tb	terminal board
tc	temperature coefficient or temperature compensating
tcxo	temperature compensated crystal oscillator
tp	test point
u or μ	micro (10^{-6})
uhf	ultra high frequency
us or μs	microsecond(s) (10^{-6})
uut	unit under test
V	volt
v	voltage
var	variable
vco	voltage controlled oscillator
vhf	very high frequency
vlf	very low frequency
W	watt(s)
ww	wire wound
xfmr	transformer
xstr	transistor
xtal	crystal
xtlo	crystal oscillator
Ω	ohm(s)
μ	micro (10^{-6})

Federal Supply Codes for Manufacturers

00213
Nytronics Comp. Group Inc.
Subsidiary of Nytronics Inc.
Formerly Sage Electronics
Rochester, New York

00327
Welwyn International, Inc.
Westlake, Ohio

00656
Aerovox Corp.
New Bedford, Massachusetts

00686
Film Capacitors, Inc.
Passaic, New Jersey

00779
AMP Inc.
Harrisburg, Pennsylvania

01121
Allen-Bradley Co.
Milwaukee, Wisconsin

01281
TRW Electronic Comp.
Semiconductor Operations
Lawndale, California

01295
Texas Instruments, Inc.
Semiconductor Group
Dallas, Texas

01537
Motorola Communications &
Electronics Inc.
Franklin Park, Illinois

01686
RCL Electronics Inc.
Manchester, New Hampshire

01730
Replaced by 73586

01884
Use 56289
Sprague Electric Co.
Dearborn Electronic Div.
Lockwood, Florida

02114
Ferroxcube Corp.
Saugerties, New York

02131
General Instrument Corp.
Harris ASW Div.
Westwood, Maine

02395
Rason Mfg Co.
Brooklyn, New York

02533
Snelgrove, C.R. Co., Ltd.
Don Mills, Ontario, Canada
M3B 1M2

02606
Fenwal Labs
Div. of Travenal Labs.
Morton Grove, Illinois

02660
Bunker Ramo Corp., Conn Div.
Formerly Amphenol-Borg
Electric Corp.
Broadview, Illinois

02799
Areo Capacitors, Inc.
Chatsworth, California

03508
General Electric Co.
Semiconductor Products
Syracuse, New York

03614
Replaced by 71400

03651
Replaced by 44655

03797
Eldema Div.
Genisco Technology Corp.
Compton, California

03877
Transistron Electronic Corp.
Wakefield, Massachusetts

03888
KDI Pyrofilm Corp.
Whippany, New Jersey

03911
Clairex Electronics Div.
Clairex Corp.
Mt. Vernon, New York

03980
Muirhead Inc.
Mountainside, New Jersey

04009
Arrow Hart Inc.
Hartford, Connecticut

04062
Replaced by 72136

04202
Replaced by 81312

04217
Essex International Inc.
Wire & Cable Div.
Anaheim, California

04221
Aemco, Div. of
Midtex Inc.
Mankato, Minnesota

04222
AVX Ceramics Div.
AVX Corp.
Myrtle Beach, Florida

04423
Telonic Industries
Laguna Beach, California

04645
Replaced by 75376

04713
Motorola Inc Semiconductor
Products
Phoenix, Arizona

04946
Standard Wire & Cable
Los Angeles, California

05082
Replaced by 94988

05236
Jonathan Mfg. Co.
Fullerton, California

05245
Components Corp. now
Corcom, Inc.
Chicago, Illinois

05277
Westinghouse Electric Corp.
Semiconductor Div.
Youngwood, Pennsylvania

05278
Replaced by 43543

05279
Southwest Machine &
Plastic Co.
Glendora, California

05397
Union Carbide Corp.
Materials Systems Div.
New York, New York

05571
Use 56289
Sprague Electric Co.
Pacific Div.
Los Angeles, California

05574
Viking Industries
Chatsworth, California

05704
Replaced by 16258

05820
Wakefield Engineering Inc.
Wakefield, Massachusetts

06001
General Electric Co.
Electronic Capacitor &
Battery Products Dept.
Columbia, South Carolina

06136
Replaced by 63743

06383
Panduit Corp.
Tinley Park, Illinois

06473
Bunker Ramo Corp.
Amphenol SAMS Div.
Chatsworth, California

06555
Beede Electrical Instrument Co
Penacook, New Hampshire

06739
Electron Corp.
Littleton, Colorado

06743
Clevite Corp.
Cleveland, Ohio

06751
Components, Inc. Semcor Div.
Phoenix, Arizona

06860
Gould Automotive Div.
City of Industry, California

06961
Vernitron Corp., Piezo
Electric Div.
Formerly Clevite Corp., Piezo
Electric Div.
Bedford, Ohio

06980
Eimac Div.
Varian Associates
San Carlos, California

07047
The Ross Milton Co.
South Hampton, Pennsylvania

07115
Replaced by 14674

07138
Westinghouse Electric Corp.,
Electronic Tube Div.
Horsehead, New York

07233
TRW Electronic Components
Cinch Graphic
City of Industry, California

07256
Silicon Transistor Corp.
Div. of BBF Group Inc.
Chelmsford, Massachusetts

07261
Aumet Corp.
Culver City, California

07263
Fairchild Semiconductor
Div. of Fairchild Camera
& Instrument Corp.
Mountain View, California

07344
Bircher Co., Inc.
Rochester, New York

07597
Burndy Corp.
Tape/Cable Div.
Rochester, New York

07792
Lerma Engineering Corp.
Northampton, Massachusetts

07910
Teledyne Semiconductor
Formerly Continental Device
Hawthorne, California

07933
Use 49956
Raytheon Co.
Semiconductor Div. HQ
Mountain View, California

08225
Industro Transistor Corp.
Long Island City, New York

Federal Supply Codes for Manufacturers (cont)

08261
Spectra Strip Corp.
Garden Grove, California

08530
Reliance Mica Corp.
Brooklyn, New York

08806
General Electric Co.
Miniature Lamp Products Dept
Cleveland, Ohio

08863
Nylomatic Corp.
Norrisville, Pennsylvania

08988
Use 53085
Skottie Electronics Inc.
Archbald, Pennsylvania

09214
G.E. Co. Semi-Conductor
Products Dept.
Power Semi-Conductor
Products OPN Sec.
Auburn, New York

09353
C and K Components
Watertown, Massachusetts

09423
Scientific Components, Inc.
Santa Barbara, California

09922
Burndy Corp.
Norwalk, Connecticut

09969
Dale Electronics Inc.
Yankton, S. Dakota

10059
Barker Engineering Corp.
Formerly Amerace, Amerace
ESNA Corp.
Kenilworth, New Jersey

11236
CTS of Berne
Berne, Indiana

11237
CTS Keene Inc.
Paso Robles, California

11358
CBS Electronic Div.
Columbia Broadcasting System
Newburyport, Minnesota

11403
Best Products Co.
Chicago, Illinois

11503
Keystone Columbia Inc.
Warren, Michigan

11532
Teledyne Relays
Hawthorne, California

11711
General Instrument Corp.
Rectifier Division
Hicksville, New York

11726
Qualidyne Corp.
Santa Clara, California

12014
Chicago Rivet & Machine Co.
Bellwood, Illinois

12040
National Semiconductor Corp.
Danburry, Connecticut

12060
Diodes, Inc.
Chatsworth, California

12136
Philadelphia Handle Co.
Camden, New Jersey

12300
Potter-Brumfield Div.
AMF Canada LTD.
Guelph, Ontario, Canada

12323
Presin Co., Inc.
Shelton, Connecticut

12327
Freeway Corp. formerly
Freeway Washer & Stamping Co.
Cleveland, Ohio

12443
The Budd Co. Polychem Products
Plastic Products Div.
Bridgeport, Pennsylvania

12615
U.S. Terminals Inc.
Cincinnati, Ohio

12617
Hamlin Inc.
Lake Mills, Wisconsin

12697
Clarostat Mfg. Co.
Dover, New Hampshire

12749
James Electronics
Chicago, Illinois

12856
Micrometals
Sierra Madre, California

12954
Dickson Electronics Corp.
Scottsdale, Arizona

12969
Unitrode Corp.
Watertown, Massachusetts

13103
Thermalloy Co., Inc.
Dallas, Texas

13327
Solitron Devices Inc.
Tappan, New York

13511
Amphenol Cadre Div.
Bunker-Ramo Corp.
Los Gatos, California

13606
Use 56289
Sprague Electric Co.
Transistor Div.
Concord, New Hampshire

13839
Replaced by 23732

14099
Semtech Corp.
Newbury Park, California

14140
Edison Electronic Div.
Mc Gray-Edison Co.
Manchester, New Hampshire

14193
Cal-R-Inc. formerly
California Resistor, Corp.
Santa Monica, California

14298
American Components, Inc.
an Insilco Co.
Conshohocken, Pennsylvania

14655
Cornell-Dublier Electronics
Division of Federal Pacific
Electric Co. Govt. Control Dept.
Newark, New Jersey

14752
Electro Cube Inc.
San Gabriel, California

14869
Replaced by 96853

14936
General Instrument Corp.
Semi Conductor Products Group
Hicksville, New York

15636
Elec-Trol Inc.
Saugus, California

15801
Fenwal Electronics Inc.
Div. of Kidde Walter and Co., Inc.
Framingham, Massachusetts

15818
Teledyne Semiconductors,
formerly Amelco Semiconductor
Mountain View, California

15849
Litton Systems Inc. Useco Div.
formerly Useco Inc.
Van Nuys, California

15898
International Business
Machines Corp.
Essex Junction, Vermont

15909
Replaced by 14140

16258
Space-Lok Inc.
Burbank, California

16299
Corning Glass
Electronic Components Div.
Raleigh, North Carolina

16332
Replaced by 28478

16473
Cambridge Scientific Ind.
Div. of Chemed Corporation
Cambridge, Maryland

16742
Paramount Plastics
Fabricators, Inc.
Downey, California

16758
Delco Electronics
Div. of General Motors Corp.
Kokomo, Indiana

17001
Replaced by 71468

17069
Circuit Structures Lab.
Burbank, California

17338
High Pressure Eng. Co., Inc.
Oklahoma City, Oklahoma

17545
Atlantic Semiconductors, Inc.
Asbury Park, New Jersey

17856
Siliconix, Inc.
Santa Clara, California

17870
Replaced by 14140

18178
Vactec Inc.
Maryland Heights, Missouri

18324
Signetics Corp.
Sunnyvale, California

18612
Vishay Resistor Products Div.
Vishay Intertechnology Inc.
Malvern, Pennsylvania

18736
Voltronics Corp.
Hanover, New Jersey

18927
GTE Sylvania Inc.
Precision Material Group
Parts Division
Titusville, Pennsylvania

19451
Perine Machinery & Supply Co.
Seattle, Washington

19701
Electro-Midland Corp.
Mepco-Electra Inc.
Mineral Wells, Texas

20584
Enochs Mfg. Inc.
Indianapolis, Indiana

Federal Supply Codes for Manufacturers (cont)

20891
Self-Organizing Systems, Inc.
Dallas, Texas

21604
Bucheye Stamping Co.
Columbus, Ohio

21845
Solitron Devices Inc.
Transistor Division
Riveria Beach, Florida

22767
ITT Semiconductors
Palo Alto, California

23050
Product Comp. Corp.
Mount Vernon, New York

23732
Tracor Inc.
Rockville, Maryland

23880
Stanford Applied Engrng.
Santa Clara, California

23936
Pamotor Div., Wm. J. Purdy Co.
Burlingame, California

24248
Replaced by 94222

24355
Analog Devices Inc.
Norwood, Massachusetts

24655
General Radio
Concord, Massachusetts

24759
Lenox-Fugle Electronics Inc.
South Plainfield, New Jersey

25088
Siemen Corp.
Isilen, New Jersey

25403
Amperex Electronic Corp.
Semiconductor &
Micro-Circuits Div.
Slatersville, Rhode Island

27014
National Semiconductor Corp.
Santa Clara, California

27264
Molex Products
Downers Grove, Illinois

28213
Minnesota Mining & Mfg. Co.
Consumer Products Div.
St. Paul, Minnesota

28425
Serv-/-Link formerly
Bohannan Industries
Fort Worth, Texas

28478
Deltrol Controls Div.
Deltrol Corporation
Milwaukee, Wisconsin

28480
Hewlett Packard Co.
Corporate HQ
Palo Alto, California

28520
Heyman Mfg. Co.
Kenilworth, New Jersey

29083
Monsanto, Co., Inc.
Santa Clara, California

29604
Stackpole Components Co.
Raleigh, North Carolina

30148
AB Enterprise Inc.
Ahoskie, North Carolina

30323
Illinois Tool Works, Inc.
Chicago, Illinois

31091
Optimax Inc.
Colmar, Pennsylvania

32539
Mura Corp.
Great Neck, New York

32767
Griffith Plastic Corp.
Burlingame, California

32879
Advanced Mechanical
Components
Northridge, California

32897
Erie Technological Products, Inc.
Frequency Control Div.
Carlisle, Pennsylvania

32997
Bourns Inc.
Trimpot Products Division
Riverside, California

33173
General Electric Co.
Products Dept.
Owensboro, Kentucky

34333
Silicon General
Westminister, California

34335
Advanced Micro Devices
Sunnyvale, California

34802
Electromotive Inc.
Kenilworth, New Jersey

37942
P.R. Mallory & Co., Inc.
Indianapolis, Indiana

42498
National Radio
Melrose, Massachusetts

43543
Nytronics Inc.
Transformer Co. Div.
Geneva, New York

44655
Ohmite Mfg. Co.
Skokie, Illinois

49671
RCA Corp.
New York, New York

49956
Raytheon Company
Lexington, Massachusetts

50088
Mostek Corp.
Carrollton, Texas

50579
Litronix Inc.
Cupertino, California

51605
Scientific Components Inc.
Linden, New Jersey

53021
Sangamo Electric Co.
Springfield, Illinois

54294
Cutler-Hammer Inc. formerly
Shallcross, A Cutter-Hammer Co.
Selma, North Carolina

55026
Simpson Electric Co.
Div. of Am. Gage and Mach. Co.
Elgin, Illinois

56289
Sprague Electric Co.
North Adams, Massachusetts

58474
Superior Electric Co.
Bristol, Connecticut

60399
Torin Corp. formerly
Torrington Mfg. Co.
Torrington, Connecticut

63743
Ward Leonard Electric Co., Inc.
Mount Vernon, New York

64834
West Mfg. Co.
San Francisco, California

65092
Weston Instruments Inc.
Newark, New Jersey

66150
Winslow Tele-Tronics Inc.
Eaton Town, New Jersey
70485
Atlantic India Rubber Works
Chicago, Illinois

70563
Amperite Company
Union City, New Jersey

70903
Belden Corp.
Geneva, Illinois

71002
Birnback Radio Co., Inc.
Freeport, New York

71400
Bussmann Mfg.
Div. of McGraw-Edison Co.
Saint Louis, Missouri

71450
CTS Corp.
Elkhart, Indiana

71468
ITT Cannon Electric Inc.
Santa Ana, California

71482
Clare, C.P. & Co.
Chicago, Illinois

71590
Centrelab Electronics
Div. of Globe Union Inc.
Milwaukee, Wisconsin

71707
Coto Coil Co., Inc.
Providence, Rhode Island

71744
Chicago Miniature Lamp Works
Chicago, Illinois

71785
TRW Electronics Components
Cinch Connector Operations Div.
Elk Grove Village
Chicago, Illinois

72005
Wilber B. Driver Co.
Newark, New Jersey

72092
Replaced by 06980

72136
Electro Motive Mfg. Co.
Williamantic, Connecticut

72259
Nytronics Inc.
Pelham Manor, New Jersey

72619
Dialight Div.
Amperex Electronic Corp.
Brooklyn, New York

72653
G.C. Electronics
Div. of Hydrometals, Inc.
Brooklyn, New York

72665
Replaced by 90303
72794
Dzus Fastener Co., Inc.
West Islip, New York

72928
Gulton Ind. Inc.
Gudeman Div.
Chicago, Illinois

Federal Supply Codes for Manufacturers (cont)

72982
Erie Tech. Products Inc.
Erie, Pennsylvania

73138
Bechman Instrument Inc.
Helipot Division
Fullerton, California

73293
Hughes Aircraft Co.
Electron Dynamics Div.
Torrance, California

73445
Amperex Electronic Corp.
Hicksville, New York

73559
Carling Electric Inc.
West Hartford, Connecticut

73586
Circle F Industries
Trenton, New Jersey

73734
Federal Screw Products, Inc.
Chicago, Illinois

73743
Fischer Special Mfg. Co.
Cincinnati, Ohio

73899
JFD Electronics Co.
Components Corp.
Brooklyn, New York

73949
Guardian Electric Mfg. Co.
Chicago, Illinois

74199
Quan Nichols Co.
Chicago, Illinois

74217
Radio Switch Corp.
Marlboro, New Jersey

74276
Signalite Div.
General Instrument Corp.
Neptune, New Jersey

74306
Piezo Crystal Co.
Carlisle, Pennsylvania

74542
Hoyt Elect. Instr. Works
Penacook, New Hampshire

74970
Johnson E.F., Co.
Waseca, Minnesota

75042
TRW Electronics Components
IRC Fixed Resistors
Philadelphia, Pennsylvania

75376
Kurz-Kasch Inc.
Dayton, Ohio

75378
CTS Knights Inc.
Sandwich, Illinois

75382
Kulka Electric Corp.
Mount Vernon, New York

75915
Littlefuse Inc.
Des Plaines, Illinois

76854
Oak Industries Inc.
Switch Div.
Crystal Lake, Illinois

77342
AMF Inc.
Potter & Brumfield Div.
Princeton, Indiana

77638
General Instrument Corp.
Rectifier Division
Brooklyn, New York

77969
Rubbercraft Corp. of CA. LTD.
Torrance, California

78189
Shakeproof
Div. of Illinois Tool Works Inc.
Elgin, Illinois

78277
Sigma Instruments, Inc.
South Braintree, Massachusetts

78488
Stackpole Carbon Co.
Saint Marys, Pennsylvania

78553
Eaton Corp. Engineered
Fastener Div.
Tinnerman Plant
Cleveland, Ohio

79136
Waldes Kohinoor Inc.
Long Island City, New York

79497
Western Rubber Company
Goshen, Indiana

79963
Zierick Mfg. Corp.
Mt. Kisko, New York

80031
Electro-Midland Corp.
Mepco Div.
A North American Phillips Co.
Norristown, New Jersey

80145
LFE Corp., Process Control Div.
formerly API Instrument Co.
Chesterland, Ohio

80183
Use 56289
Sprague Products
North Adams, Massachusetts

80294
Bourns Inc., Instrument Div.
Riverside, California

80583
Hammarlund Mfg. Co., Inc.
Red Bank, New Jersey

80640
Arnold Stevens, Inc.
South Boston, Massachusetts

81073
Grayhill, Inc.
La Grange, Illinois

81312
Winchester Electronics
Div. of Litton Industries Inc.
Oakville, Connecticut

81483
Therm-O-Disc Inc.
Mansfield, Ohio

81483
International Rectifier Corp.
Los Angeles, California

81590
Korry Mfg. Co.
Seattle, Washington

81741
Chicago Lock Co.
Chicago, Illinois

82305
Palmer Electronics Corp.
South Gate, California

82389
Switchcraft Inc.
Chicago, Illinois

82415
North American Phillips
Controls Corp.
Frederick, Maryland

82872
Roanwell Corp.
New York, New York

82877
Rotron Inc.
Woodstock, New York

82879
ITT Royal Electric Div.
Pawtucket, Rhode Island

83003
Varo Inc.
Garland, Texas

83058
The Carr Co., United Can Div.
of TRW
Cambridge, Massachusetts

83298
Bendix Corp.
Electric Power Div.
Eatontown, New Jersey

83330
Herman H. Smith, Inc.
Brooklyn, New York

83478
Rubbercraft Corp.
of America, Inc.
West Haven, Connecticut

83594
Burroughs Corp.
Electronic Components Div.
Plainfield, New Jersey

83740
Union Carbide Corp.
Battery Products Div.
formerly Consumer Products Div.
New York, New York

84171
Arco Electronics
Great Neck, New York

84411
TRW Electronic Components
TRW Capacitors
Ogallala, Nebraska

84613
Fuse Indicator Corp.
Rockville, Maryland

84682
Essex International Inc.
Industrial Wire Div.
Peabody, Massachusetts

86577
Precision Metal Products
of Malden Inc.
Stoneham, Massachusetts

86684
Radio Corp. of America
Electronic Components Div.
Harrison, New Jersey

86928
Seastrom Mfg. Co., Inc.
Glendale, California

87034
Illuminated Products Inc.
Subsidiary of Oak Industries Inc.
Anahiem, California

88219
Gould Inc.
Industrial Div.
Trenton, New Jersey

88245
Litton Systems Inc.
Useco Div.
Van Nuys, California

88419
Cornell-Dubilier Electronic Div.
Federal Pacific Co.
Fuquay-Varian, North Carolina

88486
Plastic Wire & Cable
Jewitt City, Connecticut

88690
Replaced by 04217

89536
John Fluke Mfg. Co., Inc.
Seattle, Washington

89730
G.E. Co., Newark Lamp Works
Newark, New Jersey

Federal Supply Codes for Manufacturers (cont)

90201
Mallory Capacitor Co.
Div. of P.R. Mallory Co., Inc.
Indianapolis, Indiana

90211
Use 56365
Square D Co.
Chicago, Illinois

90215
Best Stamp & Mfg. Co.
Kansas City, Missouri

90303
Mallory Battery Co.
Div. of Mallory Co., Inc.
Tarrytown, New York

91094
Essex International Inc.
Suglex/IWP Div.
Newmarket, New Hampshire

91293
Johanson Mfg. Co.
Boonton, New Jersey

91407
Replaced by 58474

91502
Associated Machine
Santa Clara, California

91506
Augat Inc.
Attleboro, Massachusetts

91637
Dale Electronics Inc.
Columbus, Nebraska

91662
Elco Corp.
Willow Grove, Pennsylvania

91737
Use 71468
Gremar Mfg. Co., Inc.
ITT Cannon/Gremar
Santa Ana, California

91802
Industrial Devices, Inc.
Edgewater, New Jersey

91833
Keystone Electronics Corp.
New York, New York

91836
King's Electronics Co., Inc.
Tuckahoe, New York

91929
Honeywell Inc.
Micro Switch Div.
Freeport, Illinois

91934
Miller Electric Co., Inc.
Div. of Aunet
Woonsocket, Rhode Island

92194
Alpha Wire Corp.
Elizabeth, New Jersey

93332
Sylvania Electric Products
Semiconductor Products Div.
Woburn, Massachusetts

94145
Replaced by 49956

94154
Use 94988
Wagner Electric Corp.
Tung-Sol Div.
Newark, New Jersey

94222
Southco Inc. formerly
South Chester Corp.
Lester, Pennsylvania

95146
Alco Electronic Products Inc.
Lawrence, Massachusetts

95263
Leecraft Mfg. Co.
Long Island City, New York

95264
Replaced by 98278

95275
Vitramon Inc.
Bridgeport, Connecticut

95303
RCA Corp.
Receiving Tube Div.
Cincinnati, Ohio

95348
Gordo's Corp.
Bloomfield, New Jersey

95354
Methode Mfg. Corp.
Rolling Meadows, Illinois

95712
Bendix Corp.
Electrical Components Div.
Microwave Devices Plant
Franklin, Indiana

95987
Weckesser Co. Inc.
Chicago, Illinois

96733
San Fernando Electric Mfg. Co.
San Fernando, California

96853
Gulton Industries Inc.
Measurement and Controls Div.
formerly Rustrak Instruments Co.
Manchester, New Hampshire

96881
Thomson Industries, Inc.
Manhasset, New York

97540
Master Mobile Mounts, Div. of
Whitehall Electronics Corp.
Ft. Meyers, Florida

97913
Industrial Electronic
Hardware Corp.
New York, New York

97945
Penwalt Corp.
SS White Industrial Products Div.
Piscataway, New Jersey

97966
Replaced by 11358

98094
Replaced by 49956

98159
Rubber-Teck, Inc.
Gardena, California

98278
Malco A Microdot Co., Inc.
Connector & Cable Div.
Pasadena, California

98291
Sealectro Corp.
Mamaroneck, New York

98388
Royal Industries
Products Div.
San Diego, California

98743
Replaced by 12749

98925
Replaced by 14433

99120
Plastic Capacitors, Inc.
Chicago, Illinois

99217
Bell Industries Elect.
Comp. Div.
formerly Southern Elect. Div.
Burbank, California

99392
STM
Oakland, California

99515
ITT Jennings Monrovia Plant
Div. of ITT Jennings formerly
Marshall Industries Capacitor Div.
Monrovia, California

99779
Use 29587
Bunker-Ramo Corp.
Barnes Div.
Landsdowne, Pennsylvania

99800
American Precision Industries Inc.
Delevan Division
East Aurora, New York

99942
Centrelab Semiconductor
Centrelab Electronics Div. of
Globe-Union Inc.
El Monte, California

Toyo Electronics
(R-Ohm Corp.)
Irvine, California

National Connector
Minneapolis, Minnesota

U.S. SALES AREAS for all Fluke products

AL, Huntsville
John Fluke Mfg. Co., Inc.
3322 S. Memorial Parkway
Suite 96
Huntsville, AL 35801
(205) 881-6220

AZ, Tempe
John Fluke Mfg. Co., Inc.
2211 S. 48th Street
Suite B
Tempe, AZ 85282
(602) 438-8314

Tucson
(602) 790-9881

CA, Irvine
P.O. Box 19676
Irvine, CA 92713
16969 Von Karman
Suite 100
Irvine, CA 92714
(714) 863-9031

Los Angeles
John Fluke Mfg. Co., Inc.
20902 South Bonita St.
Carson, CA 90746
(213) 538-3900

San Diego
John Fluke Mfg. Co., Inc.
4540 Kearny Villa Rd., Suite 115
San Diego, CA 92123
(619) 292-7656

Santa Clara
John Fluke Mfg. Co., Inc.
2300 Walsh Ave., Bldg. K
Santa Clara, CA 95051
(408) 727-0513

CO, Denver
John Fluke Mfg. Co., Inc.
1980 South Quebec St. #4
Denver, CO 80231
(303) 750-1222

CT, Hartford
John Fluke Mfg. Co., Inc.
Glen Lochen East
41-C New London Turnpike
Glastonbury, CT 06033
(203) 659-3541

FL, Orlando
John Fluke Mfg. Co.,Inc.
940 N. Fern Creek Ave.
Orlando, FL 32803
(305) 896-4881

GA, Atlanta
John Fluke Mfg. Co., Inc.
2700 Delk Rd., Suite 250
Marietta, GA 30067
(404) 953-4747

IA, Iowa City
(319) 354-2811

IL, Chicago
John Fluke Mfg. Co., Inc.
3740 Industrial Ave.
Rolling Meadows, IL 60008
(312) 398-0850

IN, Indianapolis
John Fluke Mfg. Co., Inc.
8777 Purdue Road
Suite 101
Indianapolis, IN 46268
(317) 875-7870

KS, Kansas City
(913) 381-9800

LA, New Orleans
(504) 455-0814

MA, Burlington
John Fluke Mfg. Co., Inc.
25 "B" Street
Burlington MA 01803
(617) 273-4674

MD, Baltimore
(301) 792-7060

Rockville
John Fluke Mfg. Co., Inc.
5640 Fishers Lane
Rockville, MD 20852
(301) 770-1570

MI, Detroit
John Fluke Mfg. Co., Inc.
33031 Schoolcraft
Livonia, MI 48150
(313) 522-9140

MN, Bloomington
John Fluke Mfg. Co., Inc.
1801 E. 79th St., Suite 9
Bloomington, MN 55420
(612) 854-5526

MO, St. Louis
John Fluke Mfg. Co., Inc.
2029 Woodland Parkway
Suite 105
St. Louis, MO 63141
(314) 993-3805

NC, Greensboro
John Fluke Mfg. Co., Inc.
1310 Beaman Place
Greensboro, NC 27408
(919) 273-1918

NJ, Paramus
John Fluke Mfg. Co., Inc.
P.O. Box 930
West 75 Century Road
Paramus, NJ 07652
(201) 262-9550

NM, Albuquerque
John Fluke Mfg. Co., Inc.
1108 Alvarado Drive N.E.
Albuquerque, NM 87110
(505) 881-3550

NY, Rochester
John Fluke Mfg. Co., Inc.
4515 Culver Road
Rochester, NY 14622
(716) 323-1400

OH, Cleveland
John Fluke Mfg. Co., Inc.
7830 Freeway Circle
Middleburg Heights, OH 44130
(216) 234-4540

Columbus
(614) 889-5715

Dayton
John Fluke Mfg. Co., Inc.
4756 Fishburg Rd.
Dayton, OH 45424
(513) 233-2238

OK, Tulsa
(918) 749-0190

OR, Portland
John Fluke Mfg. Co., Inc.
2700 NW 185th
Suite 2080
Portland, OR 97229
(503) 629-5928

PA, Philadelphia
John Fluke Mfg. Co., Inc.
1010 West 8th Ave., Suite H
King of Prussia, PA 19406
(215) 265-4040

Pittsburgh
(412) 261-5171

TX, Austin
(512) 459-3344

Dallas
John Fluke Mfg. Co., Inc.
14400 Midway Road
Dallas, TX 75234
(214) 233-9990

Houston
John Fluke Mfg. Co., Inc.
4240 Blue Bonnet Dr.
Stafford, TX 77477
(713) 491-5995

San Antonio
John Fluke Mfg. Co., Inc.
10417 Gulfdale
San Antonio, TX 78216
(512) 340-2621

UT, Salt Lake City
6914 So. 3000 East
Suite 206
Salt Lake City, UT 82021
(801) 268-9331

WA, Seattle
John Fluke Mfg. Co., Inc.
5020 148th Ave. N.E.
Suite 110
Redmond, WA 98052
(206) 881-6966

Service Center Areas

CA, Burbank (213) 849-4641
CA, Santa Clara (408) 727-8121
CO, Denver (303) 750-1228
FL, Orlando (305) 896-2296
IL, Chicago (312) 398-5880
MA, Burlington (617) 273-4678
MD, Rockville (301) 770-1576
NJ, Paramus (201) 262-9550
TX, Dallas (214) 233-9945
WA, Everett (206) 356-5560

For more information on Fluke products or Sales Offices you may dial (800) 426-0361 toll-free in most of the U.S.A. From Alaska, Hawaii, or Washington phone (206) 356-5400. From Canada and other countries phone (206) 356-5500.

FLUKE®

John Fluke Mfg. Co., Inc., P.O. Box C9090, Everett, WA 98206
Fluke (Holland) B.V., P.O. Box 5053, 5004 EB, Tilburg, The Netherlands. Phone (013) 673973
Litho in U.S.A. 10/84

INTERNATIONAL SALES OFFICES

Argentina ●
Coasin S.A.
Virrey del Pino 4071 DEP E-1
1430 CAP FED
Buenos Aires, Argentina
Tel: (1) 552-5248, TLX: (390) 22284

Australia ●
Elmeasco Instruments Pty, Ltd.
P.O. Box 30
Concord, N.S.W. 2137
Australia
Tel: (2) 736-2888, TLX: (790) 25887

Elmeasco Instruments Pty, Ltd.
21-23 Anthony Drive
Mt. Waverly, Victoria 3149
Australia
Tel: (3) 233-4044, TLX: (790) 36206

Elmeasco Instruments Pty, Ltd.
Professional Suites Bldg.
G.P.O. Box 2360
Brisbane 4001, Australia
Tel: (7) 369-8688, TLX: (790) 44062

Elmeasco Instruments Pty, Ltd.
G.P.O. Box 1240
Adelaide, South Australia 5001
Tel: (8) 271-1839

Elmeasco Instruments Pty, Ltd.
P.O. Box 95
Gosnells, West Australia 6110
Australia
Tel: (9) 398-3362

Austria ■
Walter Rekirsch Elektronische
Gerate GmbH & Co.
Vertrieb KG
Obachgasse 28
1220 Vienna, Austria
Tel: (222) 235555, TLX: (847) 134759

Bangladesh ●
Motherland Corporation
24 Hatkhola Road, Tikatuli
Dacca-3, Bangladesh
Tel: 257249, TLX: (950) 642022

Belgium ■
Fluke (Belgium) S.A./N.V.
6 Rue de Geneve
1140 Brussels, Belgium
Tel: (2) 2164090, TLX: (846) 26312

Bolivia ●
Coasin Bolivia S.R.L.
Casilla 7295
La Paz, Bolivia
Tel: (2) 40962, TLX: (336) 3233

Brazil ●
Fluke Brasil-Industria e
Comercio Ltda.
Al. Amazonas 422,
Alphaville, Barueri,
CEP 06400, Sao Paulo, Brazil
Tel: (11) 421-5477, TLX: (391) 1135589

Fluke Brasil-Industria e
Comercio Ltda.
Av. Henrique Valadares, No. 23/401
Rio de Janeiro, Brazil
Tel: (21) 252-1297

Brunei ●
Rank O'Connor's Berhad, Ltd.
No. 8 Block D Sufri Complex
Mile 1 Jalan Tutong
Bandar Seri Begawan
Negara Brunei Darussalam
Tel: (2) 23109 or 23557
TLX: (799) BU2265 RANKOC

Canada ●
Allan Crawford Assoc., Ltd.
6503 Northam Drive
Mississauga, Ontario
L4V 1J2 Canada
Tel: (416) 678-1500, TLX: 06968769

Allan Crawford Assoc., Ltd.
7018 Cote de Liesse
St. Laurent, Quebec
H4T 1E7 Canada
Tel: (514) 731-8564, TLX: 05824944

Allan Crawford Assoc., Ltd.
881 Lady Ellen Place
Ottawa, Ontario
K1Z 5L3 Canada
Tel: (613) 722-7682, TLX: 0533600

Allan Crawford Assoc., Ltd.
Suite 106
4180 Lougheed Hwy.
Burnaby, British Columbia
V5C 6A8 Canada
Tel: (604) 294-1326, TLX: 0454247

Allan Crawford Assoc., Ltd.
1935 30th Avenue, N.E.
Calgary, Alberta
T2E 6Z5 Canada
Tel: (403) 230-1341, TLX: 03821186

Chile ●
Intronica Chile, Ltda.
Manuel Montt 024-Of.D
Casilla 16228
Santiago 9, Chile
Tel: (2) 44940, TLX: (332) 240301

China, Peoples Republic of ●
Fluke International Corp.
P.O. Box C9090 M/S 206-A
Everett, WA 98206 U.S.A.
Tel: (206) 356-5511
TLX: 185103 FLUKE UT

Colombia ●
Sistemas E Instrumentacion, Ltda.
Carrera 13, No. 37-43, Of. 401
Ap. Aereo 29583
Bogota DE, Colombia
Tel: 232-4532, TLX: (396) 45787

Cyprus ■
Chris Radiovision, Ltd.
P.O. Box 1989
Nicosia, Cyprus
Tel: (21) 66121, TLX: (826) 2395

Cyprus, Northern
Ucok Buroteknik
2C & 2D Muftu Ziyai Street
Lefkosa, Northern Cyprus
Mersin 10, Turkey
Tel: (741) 357-20-71777, TLX: (821) 57267

Czechoslovakia ■
Amtest Associates, Ltd.
Clarence House
31 Clarence Street
Staines, Middlesex TW18 4SY
England
Tel: (784) 63555, TLX: (851) 928855

Denmark ■
Tage Olsen A/S
Ballerup Byvej 222
2750 Ballerup
Denmark
Tel: (2) 658111, TLX: (855) 35293

Ecuador ●
Proteco Coasin Cia., Ltda.
P.O. Box 228-A
Ave. 12 de Octubre 2285
y Orellana
Quito, Ecuador
Tel: (2) 529684, TLX: (393) 2865

Proteco Coasin Cia., Ltda.
P.O. Box 9733
Ave. Principal No. 204
y Calle Segunda
Urbanizacion Miraflores
Guayaquil, Ecuador
Tel: (4) 387519

Egypt and Sudan ■
Electronic Engineering Liaison Office
P.O. Box 2891 Horreya
11361 Heliopolis, Cairo
Egypt
Tel: (2) 695705, TLX: (927) 23082

England ■
Fluke GB, Ltd.
Colonial Way
Watford, Herts,
WD2 4TT England
Tel: (923) 40511, TLX: (851) 934583

Fiji ●
Awa Fiji
47 Forster Road
Walu Bay
Suva, Fiji
Tel: 312079, TLX: (792) FJ2347

Finland ■
Instrumentarium Electronics
P.O. Box 64
02631 Espoo 63
Finland
Tel: (0) 5281, TLX: (857) 124426

France ■
M.B. Electronique S.A.
Rue Fourney
P.O. Box 31
78530 BUC, France
Tel: (3) 956-8131, TLX: (842) 695414

German Democratic Republic ■
Amtest Associates, Ltd.
Clarence House
31 Clarence Street
Staines, Middlesex TW18 4SY
England
Tel: (784) 63555, TLX: (851) 928855

Germany, West ■
Fluke (Deutschland) GmbH
Oskar-Messter-Strasse 18
WG-8045 Ismaning/Munich
West Germany
Tel: (089) 96050, TLX: (841) 0522472
Rapifax: 49-89-9605166

Fluke (Deutschland) GmbH
Viertriebsburo - Dusseldorf
Meineckestrasse 53
D-4000 Dusseldorf-30
West Germany
Tel: (0211) 450831, TLX: (841) 08585576

Fluke (Deutschland) GmbH
Vertriebsburo - Hamburg
Habichthorst 42
D-2000 Hamburg 61
West Germany
Tel: (40) 5519031, TLX: (841) 02174556

Greece ■
Hellenic Scientific Representations Ltd.
11, Vrassida Street
Athens 612, Greece
Tel: (1) 7211140, TLX: (863) 219330

Hong Kong ●
Schmidt & Co (H.K.), Ltd
18th Floor, Great Eagle Centre
23 Harbour Road
Wanchai, Hong Kong
Tel: (5) 8330-222
TLX: (780) 74766 or (780) 76762

Hungary ■
Amtest Associates, Ltd.
Clarence House
31 Clarence Street
Staines, Middlesex TW18 4SY
England
Tel: (784) 63555, TLX: (851) 928855

India ●
Hinditron Services Pvt., Ltd.
69/A.L. Jagmohandas Marg
Bombay 400 006, India
Tel: 8121316, 8125344, TLX: (953) 112326

Hinditron Services Pvt., Ltd.
8th Main Road
33/44A Raj Mahal Vilas Extension
Bangalore 560 080, India
Tel: 33139, TLX: (953) 0845741

Hinditron Services Pvt. Ltd.
Shantiniketan, Office No. 6
6th Floor, 8 Camac Street
Calcutta 700 017, India
Tel: 434032, 447541

Hinditron Services Pvt. Ltd.
204-5-6 Hemkunt Tower
98 Nehru Place
New Delhi, 110019, India
Tel: 640380, TLX: (953) 314890

Hinditron Services Pvt. Ltd.
Srinath Complex, 5th Floor
1-1-58/1 to 1-1-58/11
Sarojini Devi Road
Secunderabad 500 003, India
Tel: 821117, TLX: (953) 0155575

Indonesia ●
P.T. Dwi Tunggal Jaya Sakti
P.O. Box 4435
Jalan Panglima Polim Raya #29
Kebayoran Baru
Jakarta Selatan, Indonesia
Tel: (21) 716374, TLX: (796) 47308

Ireland ■
Euro Instruments & Electronics Ltd.
Euro House
Swords Road, Santry
Dublin 9, Ireland
Tel: (1) 425666, TLX: (851) 31821

Israel ■
R.D.T. Electronics Engineering Ltd.
P.O. Box 43137
Tel Aviv 61430
Israel
Tel: (3) 483211, TLX: (922) 32143

Italy ■
Sistrel S.p.A.
Via Pelizza da Volpedo 59
20092 Cinisello Balsamo
Milan, Italy
Tel: (2) 6181893, TLX: (843) 334643

Sistrel S.p.A.
Via Giuseppe Armellini No. 39
00143 Rome, Italy
Tel: (6) 591-5551, TLX: (843) 680356

Sistrel S.p.A.
Via Cintia
Parco S. Paolo 35
80126 Naples, Italy
Tel: (81) 7679700

Japan ●
John Fluke Mfg. Co., Inc.
Japan Branch
Sumitomo Higashi Shinbashi Bldg.
1-1-11 Hamamatsucho
Minato-ku, Tokyo 105, Japan
Tel: (3) 434-0181, TLX: (781) 2424331

John Fluke Mfg. Co., Inc.
Japan Branch
SF Katsushige Building
2-45 Kohraibashi
Higashi-ku, Osaka 541
Japan
Tel: (6) 229-0871

Korea, Republic of ●
Electro-Science Korea Co.
201 Hyunjin Building
951-19 Bangbae-Dong Gangnam-ku
Seoul, Republic of Korea
Tel: (2) 583-7703, TLX: (787) 25381

Kuwait ■
Al Bahar International Group
P.O. Box 26672 Safat
Kuwait, Arabian Gulf
Tel: 848601, TLX: (959) 44822

Lebanon and Jordan ■
Mabek (Electronic Division)
P.O. Box 11-3823
Beirut, Lebanon
Tel: 812523, TLX: (923) 22889

Malaysia ●
Mecomb Malaysia SND BHD
Lot 20, Jalan 225
P.O. Box 24
Petaling Jaya, Malaysia
Tel: (3) 743422, TLX: (784) MA37764

Malta
Fabian Enterprises
20, Msida Road
Gzira, Malta
Tel: 513283/40216, TLX: (838) 1837

Mexico ●
Electronica y Tecnologia
Avanzada S.A. de C.V.
Pafnucio Padilla 53 5° Piso
Centro Comercial
53100 Ciudad Satelite
Estado de Mexico
Tel: (5) 3930902, TLX: (383) 172697

Mexicana de Electronica
Industrial, S.A. (Mexel)
Blvd. Ptd. Adolfo Lopez Mateos
Nos. 163 Col. Mixcoac
03910 Mexico
Tel: (5) 563-54-11, TLX: (383) 1771038

Nepal ●
Associated Enterprises
GPO Box 790, Pyaphal Tole
Kathmandu, Nepal
Tel: 13868

Netherlands ■
Fluke (Nederland) B.V.
Gasthuisring 14
P.O. Box 115
5000 AC Tilburg
The Netherlands
Tel: (13) 352455, TLX: (844) 52683

New Zealand ●
McLean Information Technology, Ltd.
459 Khyber Pass Road, Newmarket
P.O. Box 9464, Newmarket
Auckland 1, New Zealand
Tel: (9) 501-801; TLX: (791) NZ21570

McLean Information Technology, Ltd.
P.O. Box 496
Wellington, New Zealand
Tel: (4) 851-450 or 844-424

Norway ■
Morgenstierne & Co A/S
Konghellgate 3
P.O. Box 6688 - Rodelokka
Oslo 5, Norway
Tel: (2) 356110, TLX: (856) 71719

Oman ■
OHI Telecommunications
P.O. Box 889
Muscat
Sultanate of Oman
Tel: 703862, TLX: (926) 3168

Pakistan ●
International Operations (PAK), Ltd.
505 Muhammadi House
I.I. Chundrigar Road
P.O. Box 5323, Karachi, Pakistan
Tel: (21) 221127, TLX: (952) 24494

Peru ●
Importaciones y Representaciones
Electronicas S.A.
Avda. Franklin D. Roosevelt 105
Lima 1, Peru
Tel: (14) 28-8650, TLX: (394) 25663

Philippines, Republic of ●
Spark Radio & Electronics, Inc.
452 Shaw Boulevard
Mandaluyong, Metro Manila
Republic of Philippines
Tel: (2) 775192, TLX: (722 or 732) 27901

Poland ■
Amtest Associates, Ltd.
Clarence House
31 Clarence Street
Staines, Middlesex TW18 4SY
England
Tel: (784) 63555, TLX: (851) 928855

Portugal ■
Decada Espectral
Equipamentos de Electronica
Av. Bombeiros Voluntarios
Lote 102B, Miraflores/Alges
1495 Lisbon, Portugal
Tel: (1) 2103420, TLX: (832) 15515

Qatar ■
Technology Organization
P.O. Box 5549
Doha, Qatar
Tel: 321431, TLX: (957) 4581

Rumania ■
Amtest Associates, Ltd.
Clarence House
31 Clarence Street
Staines, Middlesex TW18 4SY
England
Tel: (784) 63555, TLX: (851) 928855

Saudi Arabia ■
Electronic Equipment Marketing Co.
P.O. Box 3750
Riyadh, Saudi Arabia
Tel: (1) 477-1650, TLX: (928) 201120

Singapore, Republic of ●
Rank O'Connor's Singapore (PTE) Ltd.
O'Connor House
98 Pasir Panjang Road
Singapore 0511
Republic of Singapore
Tel: 637944, TLX: (786) RS21023

South Africa ●
Fluke S.A. (Pty) Ltd.
Wynberg Park
777 Andries Street
Wynberg, South Africa
Tel: (11) 786-3170, TLX: (960) 424328

Spain ■
ESSA
Equipos y Sistemas S.A.
C/Apolonio Morales, 13-B
Madrid 16, Spain
Tel: (1) 458-0150, TLX: (831) 42856

Sri Lanka ●
Computerlink Data Systems, Ltd.
294 Union Place
Colombo, 2, Sri Lanka
Tel: (1) 28641/2, TLX: (954) 21321

Sweden ■
Teleinstrument AB
Maltesholmsvagen 138
P.O. Box 4490
162 04 Vallingby 4
Sweden
Tel: (8) 380370, TLX: (854) 15770

Switzerland ■
Traco Electronic AG
Jenatschstrasse 1
8002 Zurich
Switzerland
Tel: (1) 201-0711, TLX: (845) 815570

Syria ■
Mabek (Electronic Division)
P.O. Box 4238
Damascus, Syria

Taiwan ●
Schmidt Electronics Corp.
6th Floor Cathay Min-Sheng
Commercial Building,
344 Min-Sheng East Road
Taipei 104, Taiwan
Tel: (2) 501-3468, TLX: (785) 10548

Thailand ●
Measuretronix Ltd.
2102/63 Ramkamhaeng Road
Bangkok 10240
Thailand
Tel: (2) 378-2516, TLX: (788) 81143

Tunisia ■
Selep S.A.R.L.
6, Rue de Sparte
Tunis - 1000 RP
Tunisia
Tel: (1) 248093, TLX: (934) 13030

Turkey ■
Erkman Elektronik Aletler
Ticaret Anonim Sirketi
Necatiby Cad 92/3
Karakoy, Istanbul, Turkey
Tel. (11) 4415461, TLX: (821) 24399

United Arab Emirates ■
Al-Sanani Cen. Trad. Est.
P.O. Box 7187
Abu-Dhabi, U.A.E.
Tel: (2) 821370 or 821371
TLX: (958) 23966

Haris Al-Afaq, Ltd.
P.O. Box 545
Sharjah, U.A.E.
Tel: (6) 359120, TLX: (958) 68540

Uruguay ●
Coasin Uruguaya S.A.
Libertad 2529
Casilla de Correo 1400
Montevideo, Uruguay
Tel: (2) 789015, TLX: (398) 6445

USSR ■
Amtest Associates, Ltd.
Clarence House
31 Clarence Street
Staines, Middlesex TW18 4SY
England
Tel: (784) 63555, TLX: (851) 928855

Venezuela ●
Coasin C.A.
Calle 9 Con Calle 4, Edif Edinurbi
Apartado de Correos NR-70.136
Los Ruices
Caracas 1070-A, Venezuela
Tel: (2) 239-0967; TLX: (395) 21027

Yugoslavia ■
Amtest Associates, Ltd.
Clarence House
31 Clarence Street
Staines, Middlesex TW18 4SY
England
Tel: (784) 63555, TLX: (851) 928855

■ Supplied and Supported by —
Fluke (Holland) B.V.
P.O. Box 5053, 5004 EB Tilburg
Zevenheuvelenweg 53, 5048 AN Tilburg
The Netherlands
Tel: (013) 673973, TLX: 52237

● Supplied and Supported by —
Fluke International Corporation
P.O. Box C9090
Everett, WA 98206 U.S.A
Tel: (206) 356-5500
TLX: 152662 JOHN FLUKE EVT

FLUKE®

TECHNICAL SERVICE CENTERS

U.S.A.

CA, Burbank
John Fluke Mfg. Co., Inc.
(213) 849-4641

CA, Santa Clara
John Fluke Mfg. Co., Inc
(408) 727-8121

CO, Denver
John Fluke Mfg. Co., Inc.
(303) 750-1228

FL, Orlando
John Fluke Mfg. Co., Inc.
(305) 896-2296

IL, Rolling Meadows
John Fluke Mfg. Co., Inc
(312) 398-5800

MA, Burlington
John Fluke Mfg. Co., Inc.
(617) 273-4678

MD, Rockville
John Fluke Mfg. Co., Inc.
(301) 770-1576

NJ, Paramus
John Fluke Mfg. Co., Inc.
(201) 262-9550

TX, Dallas
John Fluke Mfg. Co., Inc.
(214) 233-9945

WA, Everett
John Fluke Mfg. Co., Inc.
(206) 356-5560

Other Countries

Argentina, Buenos Aires
Coasin S.A.
Tel: 552-5248/3485
TLX: 22284 COASN AR

Australia, Concord
Elmeasco Instruments Pty Ltd.
Tel: 736-2888
TLX: 25887 ELSCO

Australia, Mount Waverley
Elmeasco Instruments Pty. Ltd.
Tel: 233-4044
TLX: 36206 ELMVIC

Australia, Brisbane
Elmeasco Instruments Pty. Ltd.
Tel: 369-8688
TLX: 44062 ELMQLD

Austria, Vienna
Walter Rekirsch
Elektronische Gerate GmbH & Co.
Tel: 235555
TLX: 134759

Belgium, Brussels
Fluke (Belgium) SA/NA
Tel: 2164090
TLX: 26312

Brazil, Sao Paulo
Fluke Brasil-Industria E Comercio Ltda.
Tel: 421-5477
TLX: 1135589 FLKE BR

Canada, Calgary, AB
Allan Crawford Associates Ltd.
Tel: (403) 230-1341

Canada, Burnaby, BC
Allan Crawford Associates Ltd.
Tel: (604) 294-1326

Canada, Mississauga, ON
Allan Crawford Associates Ltd.
Tel: (416) 678-1500

Canada, St. Laurent, PQ
Allan Crawford Associates Ltd.
Tel: (514) 731-8564

Chile, Santiago
Intronica Chile Ltda.
Tel: 44940
TLX: 240301

China, Beijing
Beijing Radio Research Institute
Tel: 445612

Colombia, Bogota
Sistemas E Instrumentacion, Ltda.
Tel: 232-4532
TLX: 45787 COASN CO

Denmark, Ballerup
Tage Olson A/S
Tel: 658111
TLX: 35293 TOAS DK

Ecuador, Quito
Proteco Coasin Cia., Ltda.
Tel: 529684, 526759
TLX: 2865 PROTEC ED

Egypt, Cairo
Electronic Engineering Liaison Office
Tel: 695705
TLX: 23082

England, Watford, Herts
Fluke (Great Britain) LTD
Tel: 40511
TLX: 934583

Finland, Espoo
Instrumentarium Electronics
Tel: 5281
TLX: 124426 HAVUL SF

France, Paris
M.B. Electronique S.A.
Tel: 9568131
TLX: 695414

Greece, Athens
Hellenic Scientific Representations
Tel: 7211140
TLX: 219330

Hong Kong, Wanchai
Schmidt & Co (H.K.) Ltd.
Tel: 8330-222
TLX: 74766 SCHMC HX

India, Bombay
Hinditron Services Pvt. Ltd.
Tel: 8121316
TLX: 112326 HSPL IN

India, Bangalore
Hinditron Services Pvt. Ltd.
Tel: 33139
TLX: 0845741 HSPL IN

India, New Delhi
Hinditron Services Pvt. Ltd.
Tel: 619118
TLX: 0314890 SRMP IN

Indonesia, Jakarta Selatan
P.T. Dwi Tunggal Jaya Sakti
Tel: 716374
TLX: 47308 DIJS IA

Israel, Ramat Hasharon
R.D.T. Electronics Engineering Ltd.
Tel: 483216
TLX: 32143 RDT IL

Italy, Milan
Sistrel S.p.A.
Tel: 6181893
TLX: 334643

Italy, Rome
Sistrel S.p.A.
Tel: 5915551
TLX: 680356

Japan, Tokyo
John Fluke Mfg. Co., Inc.
Japan Branch
Tel: 434-0185
TLX: 2424331 (FLUKJPJ)

Korea, Seoul
Electro-Science Korea Co.
Tel: 583-7703
TLX: 25381 ESKOREA

Malaysia, Petaling Jaya
Mecomb Malaysia SDN BHD
Tel: 743422
TLX: MA37764 MECOMB

Mexico, Mexico D.F.
Electronica y Tecnologia
Avanzada S.A. de C.V. (ETA)
Tel: 393 09 02 or 393 57 62
TLX: 172697 BIOSME

Netherlands, Tilburg
Fluke (Nederland) B.V.
Tel: 352455
TLX: 52683

New Zealand, Auckland
McLean Information Technology, Ltd.
Tel: 501-801, 501-219
TLX: NZ21570 THERMAL

Norway, Oslo
Morgenstierne & Co. A/S
Tel: 356110
TLX: 71719

Pakistan, Karachi
International Operations (PAK), Ltd
Tel: 221127, 239052
TLX: 24494 PIO PK

Peru, Lima
Importaciones Y Representaciones
Electronicas S.A.
Tel: 288650
TLX: 25663 PE IREING

Philippines, Metro Manila
Spark Radio & Electronics Corp
Tel: 775192, 704096
TLX: 27901 RLA PH

Portugal, Lisbon
Decada Espectral Equipamentos
de Electronica, Lda.
Tel: 2103420
TLX: 15515

Republic of Singapore, Singapore
Rank O'Connor's (PTE) Limited
Tel. 637944, 239052
TLX: RS21023 OCONSIN

Republic of South Africa, Wynberg
Fluke S.A. (Pty) Ltd.
Tel: 786-3170
TLX: 424328

Spain, Madrid
Equipos y Sistemas S.A.
Tel: 458-0150
TLX: 42856 EYS E

Sweden, Vallingby
Teleinstrument AB
Tel: 380370
TLX: 15770

Switzerland, Zurich
Traco Electronic AG
Tel: 2010711
TLX: 815570 TRCO CH

Taiwan, Taipei
Schmidt Electronics Corp
Tel: 5013468
TLX: 11111 SCHMIDT
10548 EVERGOFT

Thailand, Bangkok
Measuretronix Ltd.
Tel: 378-2516
TLX: 81143 DEJOBKK TH

Turkey, Istanbul
Erkman Elektronik Aletler
Tel: 4415461
TLX: 24399

Uruguay, Montevideo
Coasin Uruguaya S.A.
Tel: 789015
TLX: UY6571 OROCUER SA

Venezuela, Caracas
Coasin C.A
Tel: 239-0967, 239-5079
TLX: 21027 EMVEN VE

West Germany, Ismaning/Munich
Fluke (Deutschland) GmbH
Tel. 96050
TLX: 0522472

FLUKE®
John Fluke Mfg. Co., Inc., P.O. Box C9090, Everett, WA 98206
Fluke (Holland) B.V., P.O. Box 5053, 5004 EB, Tilburg, The Netherlands. Phone (013) 673973
Litho in U.S.A. 10/84

Section 8
Schematic Diagrams

FIGURE NO.	NAME	DRAWING NO.	PAGE
8-1	A1A1 Thermometer PCB Assembly Component Location . . .	2160A-1610	8-2
8-2	A1A1 Thermometer PCB Assembly Schematic	2160A-1010	8-3
8-3	A1A2 Display PCB Assembly Component Location	2160A-1621	8-4
8-4	A1A2 Display PCB Assembly Schematic	2160A-1021	8-5
8-5	A2 Type Select PCB Assembly Component Location	2160A-1612	8-6
8-6	A2 Type Select PCB Assembly Schematic.	2160A-1012	8-6

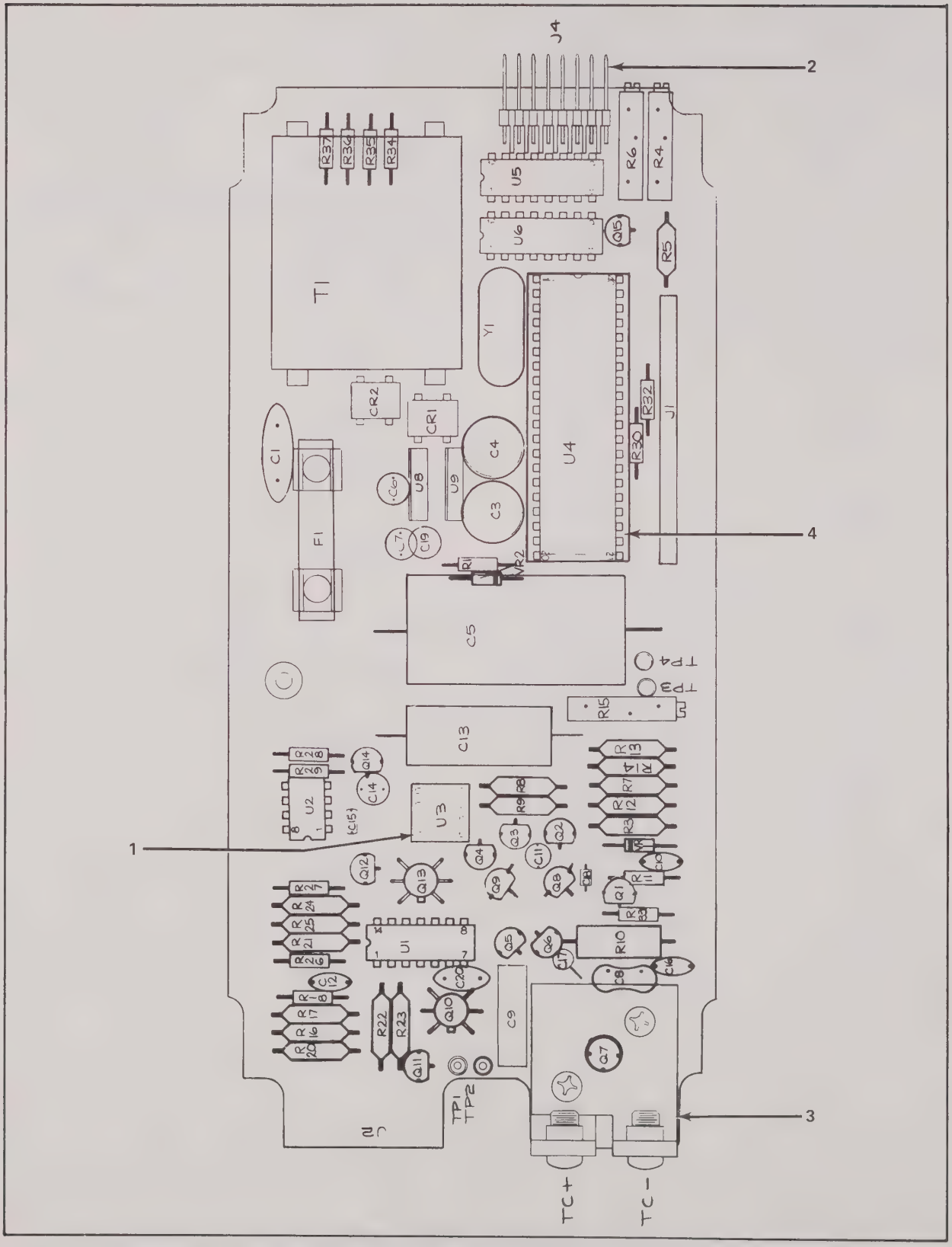


Figure 8-1. A1A1 THERMOMETER PCB ASSEMBLY COMPONENT LOCATION (2160A-1610)

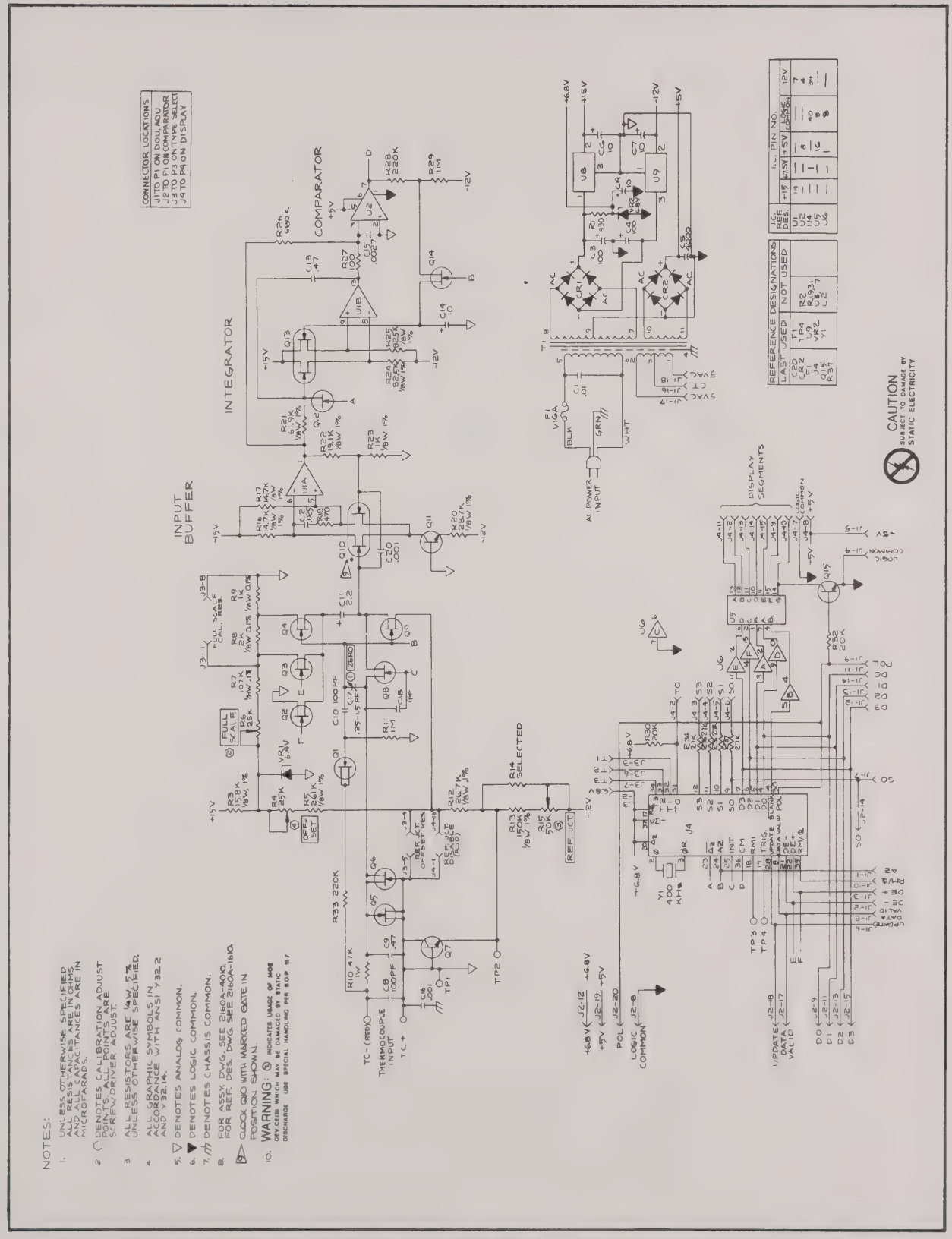

NOTES:
1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCES ARE IN OHMS AND ALL CAPACITANCES ARE IN MICROFARADS.
2. ○ DENOTES CALIBRATION ADJUST POINTS. ALL POINTS ARE SCREW DRIVER ADJUST.
3. ALL RESISTORS ARE 1/4W, 5% UNLESS OTHERWISE SPECIFIED.
4. ALL GRAPHIC SYMBOLS IN ACCORDANCE WITH ANSI Y32.2 AND Y32.14.
5. ▽ DENOTES ANALOG COMMON.
6. ▼ DENOTES LOGIC COMMON.
7. /// DENOTES CHASSIS COMMON.
8. FOR ASSY. DWG. SEE 2160A-4010. FOR REF. DES. DWG. SEE 2160A-1610.
9. CLOCK Q10 WITH MARKED GATE IN POSITION SHOWN.
10. WARNING: ⊗ INDICATES USAGE OF MOS DEVICES WHICH MAY BE DAMAGED BY ESD DISCHARGE. USE SPECIAL HANDLING PER BOP 187
CONNECTOR LOCATIONS
J1 TO P1 ON DOU, ADU
J2 TO P10 ON COMPARATOR
J3 TO P3 ON TYPE SELECT
J4 TO P4 ON DISPLAY
INPUT BUFFER
INTEGRATOR
COMPARATOR
REFERENCE DESIGNATIONS
LAST USED
NOT USED
IC DET. PIN NO.
DISPLAY SEGMENTS
CAUTION
SUBJECT TO DAMAGE BY STATIC ELECTRICITY
THERMOCOUPLE INPUT
AC POWER INPUT
LOGIC COMMON
POL
UPDATE
DATA VALID
D0
D1
D2
D3

Figure 8-2. A1A1 THERMOMETER PCB ASSEMBLY SCHEMATIC (2160A-1010)

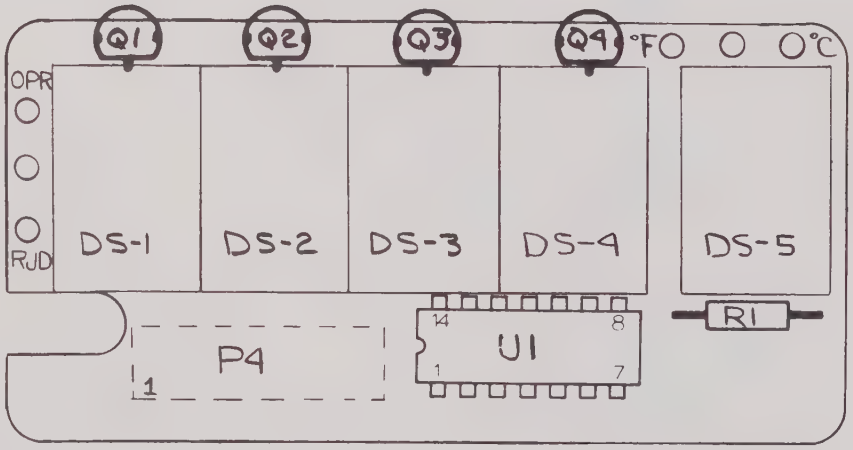


Figure 8-3. A1A2 DISPLAY PCB ASSEMBLY LOCATION (2160A-1621)

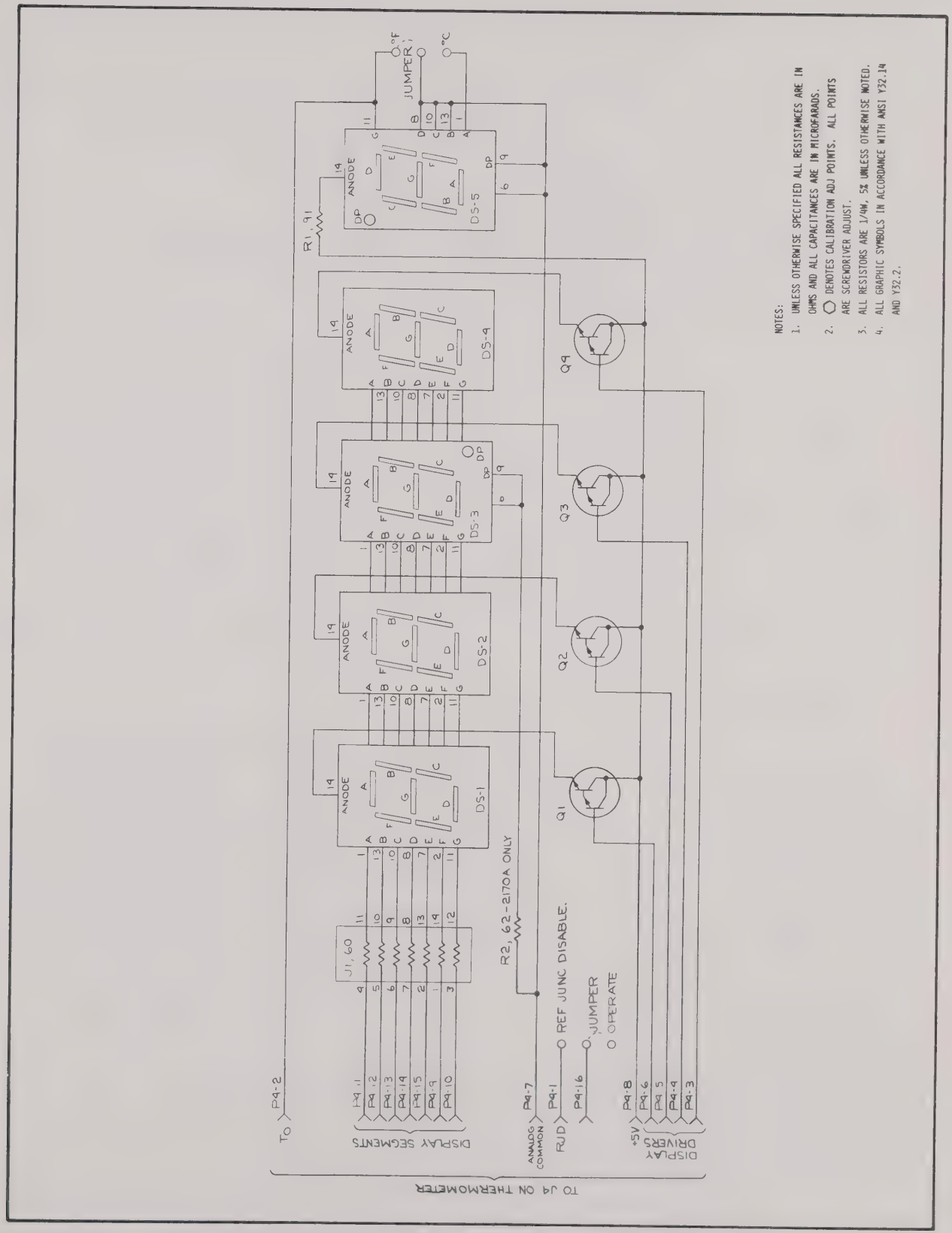


Figure 8-4. A1A2 DISPLAY PCB ASSEMBLY SCHEMATIC (2160A-1021)

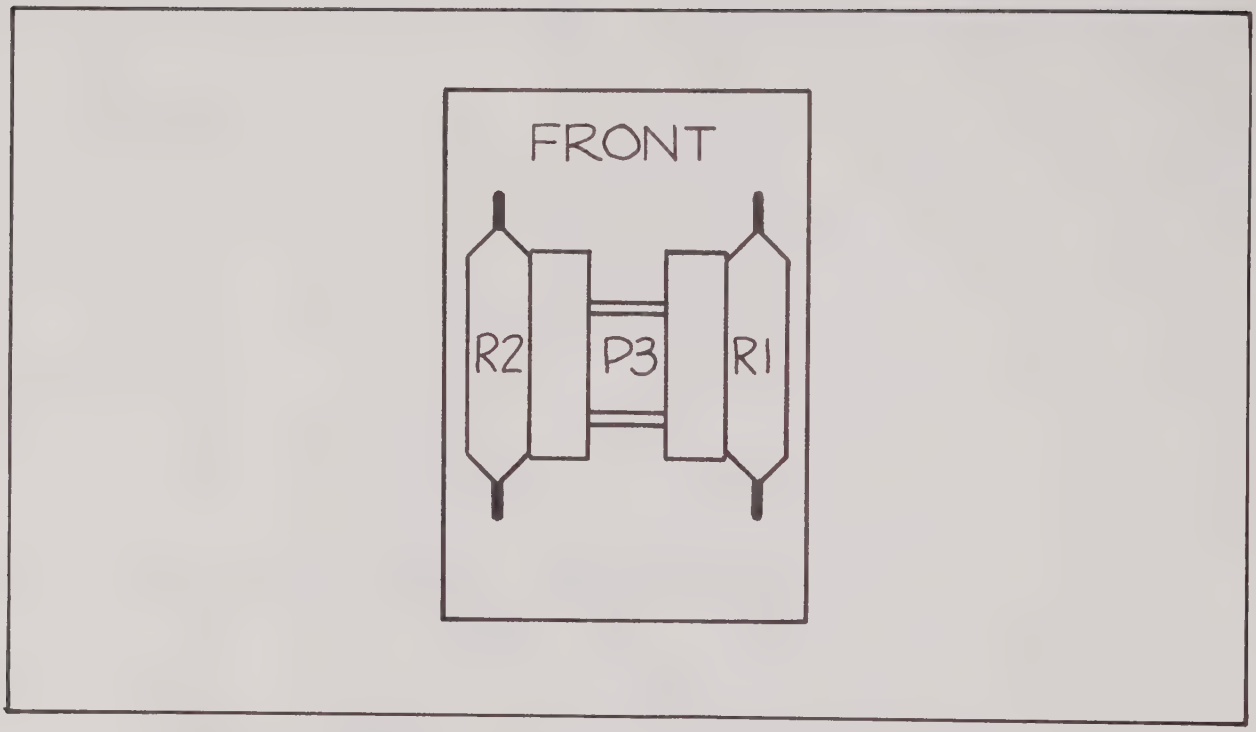
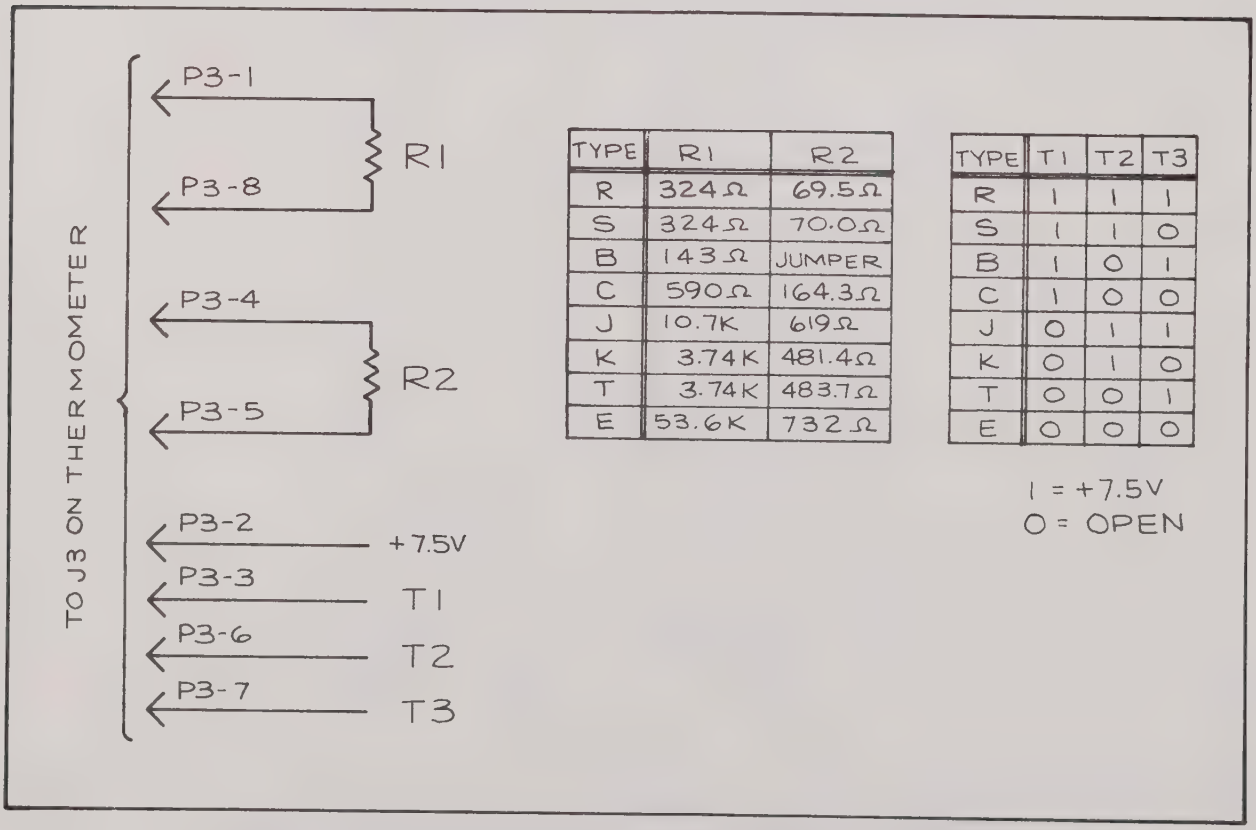


Figure 8-5. A2 TYPE SELECT PCB ASSEMBLY COMPONENT LOCATION (2160A-1612)



TYPE	R1	R2
R	324Ω	69.5Ω
S	324Ω	70.0Ω
B	143Ω	JUMPER
C	590Ω	164.3Ω
J	10.7K	619Ω
K	3.74K	481.4Ω
T	3.74K	483.7Ω
E	53.6K	732Ω

TYPE	T1	T2	T3
R	1	1	1
S	1	1	0
B	1	0	1
C	1	0	0
J	0	1	1
K	0	1	0
T	0	0	1
E	0	0	0

1 = +7.5V
0 = OPEN

Figure 8-6. A2 TYPE SELECT PCB ASSEMBLY SCHEMATIC (2160A-1012)

MODEL 2160A-04
Analog Output Unit Instruction Manual

This manual is designed as a subsection insert to Section 6, Options and Accessories, of the Model 2160A, 2165A, 2166A, 2168A, 2170A, 2175A or 2176A Instruction Manual. Prepunched pages allow this insert to be pressed into position without removing the plastic binder from the main manual

To install, first remove this cover sheet and the corner staple. Then determine the proper location in Section 6 of the main manual (numeric order according to the 600 series page numbers) and press the pages into place along the slotted binding edge.

September 1976
Part No. 429712
Litho in U.S.A.
Rev. 1 - 2/77

MODEL 2160A-02
Digital Output Unit Instruction Manual

This manual is designed as a subsection insert to Section 6, Options and Accessories, of the Model 2160A, 2165A, 2166A, 2168A, 2170A, 2175A, or 2176A Instruction Manual. Prepunched pages allow this insert to be pressed into position without removing the plastic binder from the main manual.

To install, first remove this cover sheet and the corner staple. Then determine the proper location in Section 6, of the main manual (numerical order according to the 600 Series page numbers) and press the pages into place along the slotted binding edge.

September 1976
Part No. 429704
Litho in U.S.A.
Rev. 1 2/77

MODEL 2160A-02
Digital Output Unit Instruction Manual

This manual is designed as a subsection insert to Section 6, Options and Accessories, of the Model 2160A, 2165A, 2166A, 2168A, 2170A, 2175A, or 2176A Instruction Manual. Prepunched pages allow this insert to be pressed into position without removing the plastic binder from the main manual.

To install, first remove this cover sheet and the corner staple. Then determine the proper location in Section 6, of the main manual (numerical order according to the 600 Series page numbers) and press the pages into place along the slotted binding edge.

September 1976
Part No. 429704
Litho in U.S.A.
Rev. 1 2/77